Exploring perception, learning and memory in a prodigious musical savant through comparison with other savants and ‘neurotypical’ musicians with absolute pitch

Annamaria Mazzeschi

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Dedication

Dedicated to the loving memory of

Daniele Quaratini

1981-2006

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this endeavour and the strength, dedication and perseverance in seeing this journey through to its completion.

ABSTRACT

This research contributes to the scarce literature on the perceptual and cognitive abilities of musical savants. It focuses on one prodigious savant, comparing his abilities with those of other savants and 'neurotypical' musicians with absolute pitch. Three experiments are reported. The first comprises a chordal disaggregation task, in which 6 savants and 17 'neurotypical' musicians, had to replicate the stimuli listened. While the savants as a whole outperformed the 'neurotypical' musicians, there was some overlap. The most successful participants (savant and some 'neurotypical') appeared to use a 'bottom up' strategy, whereby the lowest notes were reproduced most successfully. This suggests that savants and some 'neurotypical' musicians process chords similarly. The second experiment explored the capacity of the savant to learn and recall a novel piece of music through exposure one bar at a time. The results show that the savant found this conventional approach to learning more difficult than a comparable task, in which exposure to a different though structurally similar piece was only ever as a whole. This finding contributes to the debate on 'weak central coherence' that appears to be a feature of the cognitive style of people on the autism spectrum. The third experiment investigates whether and in what ways the prodigious savant's capacity to process and remember auditory material may be domain-specific, by comparing his ability to learn and recall a verbal stimulus with an isomorphic musical one. The prodigious savant found the text, which was shorter and less complex than the music, to be very difficult to memorise. However, another savant performed on the task better than one 'neurotypical' musician, and worse than another. This finding indicates that savants do not form an entirely homogeneous group with regard to cognitive abilities, and, in the case of the prodigious savant, adds to the debate on the potential modularity of intelligence.

Declaration of Own Work

I hereby declare that, except where explicit attribution is made, the work presented in this thesis is entirely my own.

Signed…………………………………………………………………..

The precise number of words of the thesis is 71,970. References and Appendices are not included in the word count.

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CHAPTER 1: INTRODUCTION

1.1 Personal context

My personal interest in this topic began when I was participating in the Erasmus Programme at the Institute of Education, London, through the University of Florence, where I was a Masters student. I attended a course on the Psychology of Music and Music Education. This was taught by Professor Welch who subsequently introduced me to Professor Adam Ockelford and Derek Paravicini (DP), a musical savant. DP was the first musical savant I had met; his talent astonished me, sparking my desire to discover more about 'savantism'. This led to my writing a Master's dissertation in the psychology of music, with an emphasis on musical savants in general and DP in particular.

This doctoral study is a continuation of the journey exploring the nature of musical savantism. Besides DP, I have also had the opportunity to meet several other savants in the UK and, for the first time, a musical savant from Italy whose life story is in some ways similar to DP's. Through these experiences I found that, for the savant, music and disability seem to have an inverse relationship, but the detail of such a relationship has in the past received only limited attention in the academic literature, which has focused primarily on single case studies (such as Leon Miller's account of Eddie in 1989, and Adam Ockelford's account of Derek Paravicini (DP) in 2008). Therefore, there is a need to study scientifically the musical behaviours and abilities of savants as a larger group. This research could enable us to understand their perception, memory, creativity and learning capacities better and the ways in which these do or do not correspond with comparable abilities in the non-savant population.

The role that music can play in the lives of so-called 'neurotypical'[1] people and people on the autism spectrum came to my attention through my exploration of a range of literature (including Treffert, 1989; Miller, 1989; Deutsch, 1999;

[1] The form preferred by the autism community for those who are not on the autism spectrum.

MacDonald et al., 2002; MacDonald and Wilson, 2005; Sloboda, Hermelin, and O'Connor, 1985; Sloboda, 2001; 2005; Hallam, 2006; Ockelford, 2007a; 2008) when I spent time working closely with Professor Ockelford, assisting him at DP's concerts throughout the United Kingdom. I had the opportunity to get to know DP's parents and carers, and observed his environment and the systems of safeguarding that have been put in place for him. This enabled me to see how music is a constant and vital element in his life.

Whilst I was attending one of DP's concerts (a special performance for children with autism spectrum disorders [ASD] and learning difficulties), I spoke with some of the parents who were attending, and asked them what role music played in the lives of their children, and whether it affected their lives. Their responses were universally positive; this reaffirmed my belief that music does have a positive impact on the lives of many people with learning disabilities and ASD. In addition, I have regularly attended music lessons given to autistic children, some of whom are savants, and who have varying degrees of disability, which has given me the opportunity to observe and to gain a better understanding of this complex and sometimes opaque world. The role that music plays in the lives of these children is astonishing, and the way in which they can challenge teachers, parents and friends through their high level of musical ability is often astounding, demonstrating once more the important channel that music can open for the communication of thoughts and emotions.

My interest and questions motivated me to undertake research with musical savants, and in particular to study their perception and cognition.

1.2 General context

The 'savant phenomenon' is familiar to the general public through the media exposure of certain individuals, such as Stephen Wiltshire (a prodigious artist) and DP, who has featured in various radio and television programmes across the globe, such as *Fragments of Genius* (2001), *Extraordinary People* (2007) and *60 Minutes* (2010). On YouTube and on his website, there is a wide range of comments from members of the public about the musical abilities of DP, variously insightful, and often expressing admiration or astonishment at what he can do, which demonstrate the esteem in which he is held.

In the psychology literature the term ‘savant’ is used to describe individuals with developmental disabilities who demonstrate particular and extraordinary skills. The most common areas of reported savant expertise are:

- music (Miller, 1989; Rimland, 1978; Ockelford, 2008);
- language (O’Connor and Hermelin, 1991) including hyperlexia and facility with foreign-language acquisition (Wallace, Happé and Giedd, 2009);
- art, such as drawing (Selfe, 1983; 2011) and sculpture (Treffert, 1989);
- mental calculation (Wallace, Happé and Giedd, 2009);
- calendrical calculation, an unusual ability to name the corresponding weekday for any given date (Cowan, O’Connor and Samella, 2003);
- mechanical aptitude (Tredgold, 1914);
- spatial skills, mathematical calculation, prime number derivation (Sacks, 1985);
- memory feats (Rimland, 1978; Heavey, Pring and Hermelin, 1999; Ockelford, 2012) and
- sensory sensitivity and athletic performance (Hill, 1974; Rimland, 1978; Cobrinik, 1982).

It is not uncommon for some savants to have multiple skills (Hill, 1974; Rimland, 1978; Cobrinik, 1982). According to the literature, the most common savant skill is musical ability (Treffert, 2000), including absolute pitch ability (Miller, 1989). Many play the piano by ear using this skill. Absolute pitch (AP) is the ability to identify or produce the pitch of a sound without any reference point; it is prevalent among children with autism (Rimland and Fein, 1988) and is sometimes regarded as evidence of a high level of general musicality.

While a limited amount of research has been done with musical savants over many years, largely by researchers working in the field of cognitive psychology (Rimland, 1978; Hill, 1978; Miller, 1989; Heaton and Wallace, 2004; Heaton et al., 2008; Pring, 2005a; Ockelford and Pring 2005; 2006; 2007b; 2008; 2012; 2013) with some commentaries also in the fields of psychiatry and neurology (Treffert, 1989; 2000; Sacks, 2007) there are still many gaps in our knowledge. A key gap is our understanding of how AP impacts on musical learning and recall, and the wider development of exceptional musicality, and so this was a feature of musical savantism that seemed to be particularly important to study.

1.3 Aims and research questions

Within this context, the aim of the current doctoral research was to learn more about musical savants, building on earlier work, including that cited above and Ockelford (2008; 2012), Mazzeschi (2007), Mazzeschi et al. (2011), Heaton, Hermelin and Pring (1998) and Heaton (2003). This was with the intention of examining a specific case (*cf.* Robson, 2008) – DP – and contextualising his abilities in relation to those of other savants (N = 5) and of 'neurotypical' musicians with AP (N = 17). Through a series of music-psychological experiments, the research would involve describing and evaluating savants' abilities, in particular their capacity for processing pitch (perception), musical structure (cognition) and their storage and retrieval of musical and verbal data (learning and memory). It is important to note that, in keeping with current thinking in disability studies (Lerner and Straus, 2006; Straus, 2011), the emphasis of this project is on *abilities* rather than *disabilities*, on strengths rather than weaknesses, and on valuing different cognitive styles rather than viewing them as a 'problem to be solved'.

My research is driven by three main questions, which, as we shall see, arose from the literature as well as my direct observations of musical savants in action:

Perception

1) To what extent and in what ways are the chordal disaggregation abilities and strategies displayed by DP typical of other savants and 'neurotypical' musicians with AP? (And specifically, what (if any) is the impact of chordal size and structure?)

Learning and memory in music

2) To what extent and in what ways is DP's capacity to learn music by ear affected by the mode of presentation? (And specifically, what impact does the enforced strategy of breaking a memorisation task down into small chunks and doing 'a bit at a time' have compared with attempting to learn a piece 'all the way through'?)

Learning and memory in verbal material

3) To what extent and in what ways is DP's capacity to learn and recall music domain-specific: in particular, how does it compare with his ability to learn and recall verbal material? (And how does this compare with another savant and 'neurotypical' musicians with AP?)

1.4 Structure of the thesis

The thesis is divided into three main sections:

- *SECTION I: Introduction, Context and Background Literatures*
- *SECTION II: Fieldwork*
- *SECTION III: Discussion and Conclusions*

The first section encompasses Chapters 1 and 2. Chapter 1 (this chapter) provides a personal and general context and an overview of the thesis. Chapter 2 is termed 'Review of research and theories of autism and musical savants: absolute pitch (AP) and memory' and outlines the history of previous research that has been conducted into autism and savant syndrome, and it provides also a literature review on pitch perception (in particular AP), musical learning and memory, describing relevant music-psychological theories, followed by the most recent thinking on savants' abilities and how they relate to the notion of intelligence.

The second section is the empirical segment entitled 'Fieldwork', which comprises Chapter 3 'AP Study', Chapter 4 ' Musical Memory test *Classical Turn'* and Chapter 5 'Verbal memory test'. Chapter 3 describes an AP experiment involving the disaggregation of chords, which was conducted with both savants and non-savant participants. Chapter 4 describes a musical learning task, investigating the learning and performance strategies used by DP. Chapter 5 illustrates a verbal memory test conducted by two musical savants (DP and GN) and two comparison participants (LP and AN).

The third section 'Discussion and Conclusion' comprises Chapters 6 and 7. Chapter 6 discusses the findings from the fieldwork phase of the study and compares them with results from previous research. Chapter 7 summarises the main findings, explains how these make a contribution to knowledge, and discusses some psychological and pedagogical implications for those researching and working with savants, with suggestions for further research.

CHAPTER 2: REVIEW OF RESEARCH AND THEORIES OF AUTISM AND MUSICAL SAVANTS: ABSOLUTE PITCH (AP) AND MEMORY

2.1 Introduction

This chapter provides an overview of the main literature relating to autism and savants, followed by a general discussion of research into perception, learning and memory in the general population, and then specifically in those with autism, including savants. It provides a summary of the literature that underpins and is of general relevance to the three studies described in this thesis. In subsequent chapters, research that appertains to each study will be discussed in more detail.

2.2 Autism

The term ‘autism’ was first used by Kanner (1944) in the expression *early infantile autism*, describing children showing, amongst other characteristics, aloneness, mutism or language that failed to convey meaning to others, suspected deafness, obsessive desire for sameness, use of the third person rather than personal pronouns, echolalia, literalness, fascination with spinning objects and rhythm, ‘over-all serious-mindedness’, phenomenal rote memory, and many repetitive and stereotyped behaviours (Kanner, 1944). In the same period, Asperger in Austria used the term autism referring to what is now known as ‘Asperger Syndrome’ (Asperger, 1938); it is not clear whether Kanner derived the term separately from Asperger (Lyons and Fitzgerald, 2007). Today, autism is defined as a disorder of neurodevelopment, characterised by deficits in social interaction and communication, and restricted, repetitive and stereotyped patterns of behaviour, interests and activities (Caronna, Milunsky and Tager-Flusberg, 2008). The American Psychiatric Association (APA, 2013) defines autism using three main criteria, each of which must have been present from childhood for a diagnosis to be made: a qualitative impairment in social interaction, a qualitative impairment in communication, and restricted, repetitive and stereotyped patterns of behaviour, interests and activities. This triad of symptoms cannot be explained by a single cause at the genetic, neural or cognitive level (Brunsdon and Happé, 2013). The latest edition of the Diagnostic and Statistical Manual of Mental Disorders (5^{th} ed.; DSM-5) (American Psychiatric Association, 2013) does not have a separate category for Asperger's Syndrome, and merges social and communication symptoms into one domain.

There are currently three main theories that aim to explain the nature of the autism spectrum: Theory of Mind (ToM), Weak Central Coherence (WCC) and Executive Dysfunction (ED). Frith and Happé (1994) considered each of them related to a particular 'deficit' and an area of potential achievement.

Theory of Mind is the ability to detect another person's thoughts and feelings. Baron-Cohen, Leslie and Frith (1985) suggested that this ability is impaired in those with autism, resulting in difficulties with social interaction. The potential area of achievement is to think truly original thoughts (Happé, 2005). WCC is described as a cognitive style (Frith, 1989; Frith and Frith, 2003; Happé and Frith, 2006), which is characterised by a bias towards local rather than global information processing (Happé, 1999, p. 216). People with ASD are said to demonstrate WCC as they often focus on specific fragments of information, rather than the sum of these fragments. Children with ASD have been found to perform much better than their typically developing peers on tasks where local processing facilitates performance. However, they are less skilled at tasks requiring visuo-spatial integration (Frith and Happé, 1994). Pellicano et al. (2006) examined the validity of the WCC theory in the context of multiple cognitive capabilities and deficits in autism, using tasks pertaining to visuo-spatial coherence, false-belief understanding and executive control. Their results provided partial support for the construct of WCC at the visuo-spatial level in children with ASD. This theory may explain communication difficulties experienced in communication by those with autism. The potential area of achievement in the enhanced perception of detail can lead to the development of some savant-like abilities. Happé and Vital (2009) indicate that the ability to process local information, (e.g. preference for detail over archetype and generalisation), detail-focused attention and memory predispose children to the development of talent. The Executive Dysfunction, described as a difficulty in regulating cognitive functions (Hill, 2004; South, Ozonoff and McMahon, 2007) could be linked to restricted repetitive and stereotyped patterns of behaviour, interests and activities, which, given the opportunity can lead to the development of exceptional skill. Music is one of these domains of unusual interest and activity (Ockelford, 2013).

2.3 Musical Savants

2.3.1 Defining savants

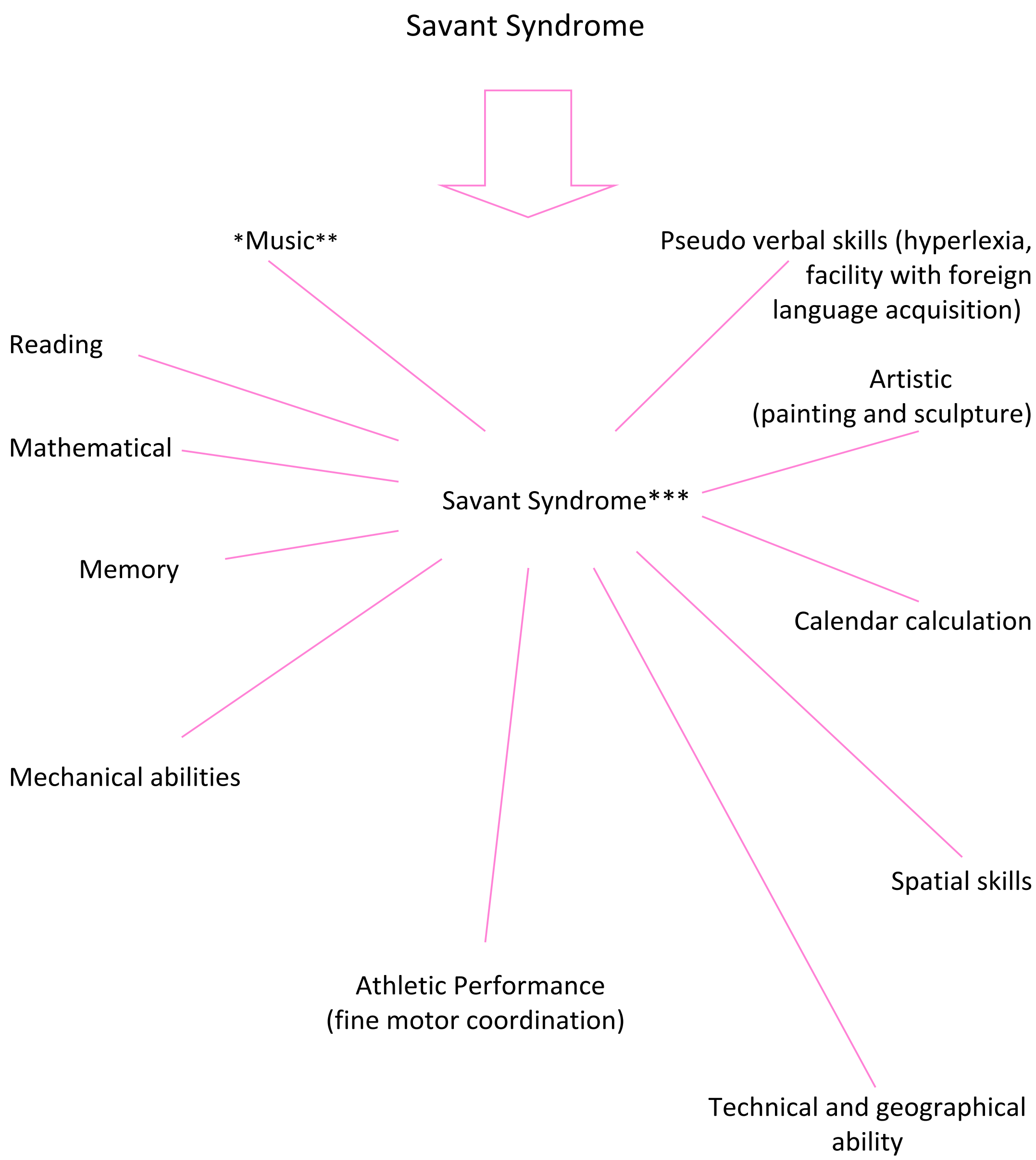
The American Psychological Association (APA) Dictionary (2006) defines an 'idiot savant' as 'a person with mental retardation who possesses a remarkable, highly developed ability or talent in one area, such as rapid calculation, expertise in playing music, or feats of memory. Such people are rare, and this ability usually occurs in those with mild or moderate mental retardation, with or without Autism Spectrum Disorders. It further defines savant as 'a learned individual, or an individual who demonstrates exceptional or remarkable and unusual intellectual prowess or skills or a person with mental retardation or an autistic spectrum disorder who demonstrates exceptional, usually isolated, cognitive abilities'.

The savant literature, whilst supporting the above definition, suggests that there are several other factors that need to be taken into account in order to understand savantism. The condition is reported to be genetic, or acquired pre-, peri- or post-natally or later in childhood, or, somewhat controversially, even as an adult (Treffert, 2000). Savant skills can co-exist with various developmental or acquired disabilities. These include disorders such as autism, learning difficulties, brain injury, trauma or neurological disease (Treffert, 2009).

A traditional view is that savants have limited understanding of emotions, such that their performances and behaviours are observed to be mechanical, repetitive or imitative, as opposed to prodigies who may develop a more homogeneous intellectual profile (Treffert, 2000). Savants have also been reported to display eccentric behaviour and severe disorders of attention in areas other than that of their particular interest or interests (Rimland, 1978).

Savant abilities usually appear at an early age and, given an appropriate environment, can flourish, often through the assistance and support of teachers, caregivers, and parents (Ockelford, 2008). Their abilities are reported to be developed through concentration and a fixation on detail, often involving long and repetitive patterns of practice that, for 'neurotypical' individuals, could appear meaningless or dull (Happé and Frith, 2010) (although comparable patterns of behaviour bear a striking resemblance to the long hours of practice and repetition that elite 'neurotypical' performers in any domain necessarily undertake). It is argued that savants therefore develop and sustain their highly specialised abilities in the same way as any other expert performer. The most common areas of savant expertise are illustrated in Figure 2.1.

When researchers describe savants, they are likely to be speaking from the experience and knowledge that they have gained through their work – and the values, beliefs and epistemological backgrounds of their thinking. Therefore, their definitions are likely to be grounded in their experience of particular examples of savantism and through the lens of their sphere of research. Moreover, within the savant population there is heterogeneity, with evidence that each savant is distinct and may well have contrasting characteristics from others (Ockelford, 2008). Hence, it is very difficult to have a clear and concise understanding of these special people.



*The most common savant skill is musical ability (Treffert, 2010).
**All have perfect pitch (Miller, 1989).
***Multiple skills are common (Hill, 1974; Rimland, 1978; Cobrinik, 1982; Heaton and Wallace, 2004).

Fig. 2.1 Reported areas of exceptional ability associated with the term 'savant syndrome' (based on reports by Tregold, 1914; Anastasi and Levee, 1960; Viscott, 1970; Hill, 1974; 1977; Rimland, 1978; Sloboda, Hermelin and O'Connor, 1990a; Snyder and Mitchell, 1999; Miller, 1989; Treffert, 2000; Wallace, Happé and Giedd, 2009; Heaton and Wallace, 2004; Happé and Frith, 2010).

2.3.2 Prevalence

Various attempts have been made to determine the number of people with savant skills, both within the population as a whole and amongst those with a congenital or acquired learning disability. In 1977, Hill conducted a survey in 300 public residential facilities in the USA for the 'mentally retarded', reporting 54 'idiot savants' within a population of 90,000 residents (0.06%). That is, approximately one in every 2,000 residents with a developmental disability, learning difficulty, or brain injury showed savant skills (Hill, 1977). Although this was important initial work, problems in interpretation arose with this survey data as there were no standard criteria by which savants were being defined and the survey was conducted only in public residential facilities. No other sources, such as private institutions, voluntary organisations or parent groups were used. Subsequently, in 1978, Hill expanded on previous research findings by performing a meta-analysis of 63 publications. He reported that, as with the autistic population as a whole, boys outnumbered girls by three to one in this sample of savants (105 individuals). He devised specific subheadings within savantism, such as concrete thinking, sensory deprivation, compensation, genetics, memory and concentration, then provided theoretical explanations for each. He attempted to collate and organise the work of other authors and researchers, generally referring to behavioural characteristics rather than medical diagnoses. This broader approach to his research question notwithstanding, Hill's previous results regarding the overall prevalence of savants were confirmed.

In the same year Rimland (1978) concluded from a series of case studies that approximately 10% of children on the autism spectrum have some savant abilities. In order to gather more information regarding the case studies that were on file, 120 questionnaires were completed by the families of the young people concerned. These posed more detailed questions, concerning the kind of special ability the child had, the age at which it first appeared and whether he or she showed multiple abilities. Rimland suggested that autism could form the basis of savant abilities implying a link between autism and savantism. Rimland's article (1978) is not presented according to current academic practice, in that within the article it is not possible to check the details of the questionnaire that he administered to the families. Therefore, the prevalence of savants suggested by this research must be viewed with caution.

Twenty-two years later, Saloviita, Ruusila and Ruusila (2000) reported that the general incidence of savant syndrome in Finland was 1.4 per 1,000 people with 'mental retardation'. They reported 45 cases of savant syndrome; in their research they observed that the most common exceptional skill was calendar calculation, followed by feats of memory.

In 2009, Howlin et al. conducted research with 137 people with a diagnosis of autism. Using a Wechsler test score they found that 28.5% met the criteria for possessing a savant skill. These individuals displayed an exceptional skill in terms of performance on intelligence subtests, or were reported by their parents to have savant skills in memory, music or calculation. When compared to Rimland's (1978) research, these findings suggest that the prevalence of outstanding abilities inside the autistic population has appeared to increase in the last thirty years, as has the population of autistic people; Baron-Cohen, Leslie and Frith, 2008) reported that thirty years ago autism was rare (four in 10,000), whereas today it is more common (one in 100). It is not known whether this is due to refinements in the ability to define and recognise this condition. It could be that the prevalence of savants has appeared to increase in recent years due to the fact that the definition of savantism has become broader.

2.3.3 History and contemporary definitions

For more than 200 years, observations have been made, anecdotal reports have appeared (e.g. about 'Blind Tom' in the *Manchester Courier* of 26 September 1866) and some research conducted into the savant phenomenon. In spite of various attempts, there has been no precise definition of savantism (Simner, Mayo and Spiller, 2009), due to the fact that no standard criteria have been established for evaluating this condition. In order to have a better understanding of this special group, we must come back to the historical term ‘idiot savant’ and the use of the term ‘savant’ in order to comprehend the ways that these terms have evolved.

Benjamin Rush provided one of the earliest reports of what is now commonly referred to as savant syndrome, although it was not labelled as such at the time. In 1789, he described in detail the lightning calculating ability of Thomas Fuller ‘who could not comprehend anything, theoretical or practical, more complex than counting.’ When Fuller was asked how many seconds a man who was 70 years, 17 days, and 12 hours old had lived, he responded with the correct answer of 2,210,500,800 in 90 seconds, even correcting for the 17 leap years included (Treffert and Christensen, 2005).

One hundred years after Rush described this condition, Langdon Down, in 1887, coined the term ‘idiot savant’, and this remained in popular use for several decades. Binet (1894) subsequently used the label to describe persons who, in spite of a low level of general cognitive ability, nevertheless showed some outstanding skill in an isolated domain. Around the turn of the 20th century, the word ‘idiot’ did not have the negative implications that it now bears. Following Binet’s pioneering work on intelligence, it became an accepted medical and psychological term referring to a specific level of intellectual functioning, based on I.Q. The word ‘savant’ was derived from the French verb ‘savoir’, ‘to know’ meaning a learned individual (Down, 1887). Observation of individuals with severe learning disabilities who also displayed advanced levels of learning, albeit in very narrow ranges, led to the descriptive, juxtaposition of the two words ‘idiot savant’ (Down, 1887).

For more than a century, ‘idiot savants’ attracted the attention of people working in the field of mental disability (e.g. Sequin, 1866; Ireland, 1900;

Goddard, 1914; Tredgold, 1914). They mostly used anecdotal reports based on the informal observation of cases, followed by further descriptions based on case studies, which described individuals who were able to make very fine sensory discrimination. They also reported cases in which an idiot savant displayed remarkable mechanical dexterity, something since observed to be quite rare among savants; in addition, music, unusual mathematical and other skills were discovered (Tredgold, 1914; Gottard, 1914).

Anastasi and Levee (1960) provided one of several reports describing idiot savants whose special abilities were in music. The individual they described experienced problems with everyday activities, and had difficulties with remembering people. He disliked anything that disrupted his routine and threatened his security. According to the author, the aetiology of the case involved the interaction of at least three factors: deficiency in abstraction (resulting from brain damage), auditory hypersensitivity and the emotional environment at home.

In this period the link between autism and savantism became apparent. In 1972, Goodman used the term autistic savant to describe 'idiot savant abilities' in the autistic population, stressing the combination of their common behaviour and mental characteristics. In his paper he described discrepancies in mental function, in particular visual discrimination, memory and associational processes, in an autistic savant.

Hill (1974) attempted to undertake an initial categorisation of idiot savant abilities based on preceding descriptions made about savants. He listed savant cases of fine sensory discrimination, and mechanical, musical, memorisation and calendrical calculating abilities. However, he did not explain each case of savant skills in detail. He suggested that no attempt had been made to find individuals who might have 'special abilities' who were not diagnosed as having learning difficulties. In 1978, Hill tried to clarify the ambiguity of the previous definition, explaining what low general intelligence means, in the sense that it could be referred to as 'mental retardation' per se (in medical terms), or individuals with low intelligence relative to the population of the 'mentally retarded'. He arrived at the following definition: 'A savant is a mentally retarded person demonstrating one or more skills above the level expected of non retarded individuals' (pp. 277–298). He reported anecdotal evidence of people with an extraordinary ability to identify substances by smell, and others with abilities for painting and woodcraft, and also highlighted the high proportion of savants in the autism population.

In the same year, Rimland (1978) continued Hill's line of research. The special abilities that were most often reported were exceptional memory and musical skills, such as playing instruments, singing, displaying absolute pitch, composing, performing and improvising. Rimland also described some autistic savants with mathematical talents, such as the capacity to discover prime numbers, to factorise and to determine square roots, and calendrical calculation abilities. Also mentioned were geographical skills, such as reading maps, remembering directions and locating places, as well as astronomy and photographical memory. Additionally, art, pseudo-verbal skills (spelling and pronunciation with no understanding), mechanical skills and high levels of coordination were noted to be present in several children, some of the whom appeared to possess multiple special abilities. In 1988, Charness, Clifton and MacDonald coined the term 'monosavant', meaning a savant with one area of special ability in the context of disability.

Treffert, in his book *Extraordinary People* (1989), coined the expression 'savant syndrome', which is a widely used label in the popular media, although the condition is sometimes simply known as 'savant' or 'autistic savant'. Treffert's definition was based on the case studies that he had observed of savant patients in his psychiatric clinic. Treffert described their special abilities in different fields, such as music, memory and maths; he also reported that savants are found in a very small percentage of the population, stating that there are fewer than 100 savants recognised in the world (although, as the data reported below indicate, this is almost certainly an underestimate). Furthermore, he divided savants into two categories: ‘prodigious’ and ‘talented’. In the former, a much rarer condition, the ability or brilliance is not only spectacular in contrast to the learning difficulty, but would be noteworthy even if viewed in a ‘neurotypical’ person. In other words, these savants show superior levels of skill relative to those without impairments, and their ability is exceptional by any standards. In the latter (termed ‘talented’), a savant’s skills are remarkable only in contrast to their disability, showing areas that are strong relative to their impairments in other areas, but not with reference to a non-disabled population.

In the same year, 1989, Leon Miller, a cognitive psychologist, wrote a book reporting his research on musical savants, which explained in more detail a case study of a young musical savant called Eddie. Miller used standardised tests and experiments to gather additional data about Eddie in order to identify the musical savant’s condition better. He also described other musical savants in a systematic way, providing extensive information about their cognitive and musical abilities.

Miller and Treffert used different approaches to define the condition, likely due to their contrasting working backgrounds. Whilst Miller, alongside observation, used some standardised tests and controlled experiments, Treffert generated his evidence solely through observation, as previously mentioned. Even though Treffert’s work was not based explicitly on a systematic methodology, the observational information he offers is useful and interesting for a better comprehension of the subject.

Smith and Tsimpli (1995) in their book, *The Mind of a Savant: Language, Learning and Modularity*, describe a savant who had difficulty with everyday tasks and who was unable to look after himself, yet could read, write, translate and communicate in fifteen to twenty different languages. Other research was reported by Nettelbeck and Young (1996), who wrote an article about intelligence that described those with 'splinter skills' that were only marginally above a non-savant person's general level of functioning. They also identified two features of savant performance: memory and cognitive processes dedicated to a specific ability, and discussed diverse models of intelligence, arguing that savant skills were not indicative of intelligence. In 1998, Mottron and his collaborators described the exceptional memory performance in an autistic savant, discovering that the outstanding episodic memory shown by some savants could be linked to a particularly high resistance to the introduction of any interfering material designed experimentally to disrupt memory.

Various authors (such as Goodman, 1972; O'Connor and Hermelin, 1994) have suggested that, in order to understand savants better, social and communicative characteristics should be also taken into account, which is why there has been a move towards calling savants '*autistic* savants'. One interpretation is that this is just a terminological difference, but there is evidence that sometimes behavioural and social problems are related to cognitive deficits (Frith, 1989).

Heaton and Wallace (2004) proposed that the discussion about intelligence should differ from IQ testing conceptions and should include discrepancies between functional impairments and unexpected skills. As we have seen, they examined the notion of savantism by considering these abilities in the context of neuropsychological accounts of autism. Gordon (2005) described and explained special ability, not only among young children, but also within the population of elderly people who are affected by fronto-temporal dementia, discussing possible links between both groups. Ockelford and Pring (2005) conducted limited research involving DP, exploring aspects of his musical mind and debating the nature of musical learning, memory and creativity.

Researchers such as Heaton and Wallace (2004) and Pring (2005b) have approached the topic of savantism by drawing on the neuropsychological basis of autism, explaining this phenomenon via theories such as Theory of Mind (ToM) and Weak Central Coherence (WCC) (Frith, 1989), described above. However, recent reports (Happé and Frith, 2006; Happé and Boot, 2008) have provided a more nuanced view of this theory, suggesting that the deficit detected in general processing could be explained as a processing bias: a preference for local processing rather than a deficit in global processing ability.

The neurologist Oliver Sacks, described some cases of savantism in his book *Musicophilia* (2007) using a different approach that was more focused on the individual. He emphasised the important role that music plays in their lives and described their special behaviours. Based on their stories and memories, he described extreme cases of some of the patients in his clinic, providing a general profile of their attitudes and focusing on their special skills.

Ockelford, in his book *Music for Children and Young People with Complex Needs* (2008), described six savants (pp. 252–257) and disputed the Treffert (1989; 2000) and Nettelbeck and Young (1996) classifications by arguing that savants are different from each other and cannot reasonably be placed in two categories; rather, their skills are better regarded as existing on a number of continua. In addition, as Ockelford suggested (2008, pp. 259ff) all savants, notwithstanding how talented or disabled they are, will benefit from systematic and sustained educational input.

More explanations and theories regarding savant syndrome have emerged in the last few years. The current debate is focused on why people with an autism spectrum disorder (ASD) exhibit outstanding isolated talents more than any other group with learning difficulties, while on the other hand acknowledging that not every person with ASD shows savant skills (Treffert, 2009). The ability to process local information despite apparently global deficits (WCC) plays a key role in the definition. ‘Neurotypically’ developing individuals show a natural aptitude for coherence in processing stimuli as a whole; on the other hand, individuals with autism tend to show a weak sense of coherence, and a preference for processing parts over wholes, i.e., at the expense of focusing on higher-level meaning. In some cases (such as music and art), this focus on parts rather than wholes could become an adaptive strategy. It has been suggested, for example, that memory and detail-focused attention predispose the individual to the development of advanced ability (Happé and Vital, 2009). It is theorised that the ‘segmentation strategy’, that is being able to decompose and recompose material, is an information processing style that is a precursor to savant skills (Pring and Hermelin, 2002) and is required in order to have an enhanced ability in a given field, such as art, music or maths. The segmentation strategy then could become an adaptive feature (Pring, 2008).

Baron-Cohen et al. (2009) argue that superior sensory acuity across modalities underlies such detailed focusing, forming the basis of strong systemising, typical of people with ASD. Locally orientated processing and detection of patterns in the environment are believed to underlie the high incidence of savant skills in autism (Mottron, Dawson and Soulières, 2009). The ability to process particular information has been reported to play an important role in predisposing an individual to special skills of a savant type. As already mentioned, obsessiveness and repetition can be the drive to develop special ability, but also, as Baron-Cohen and his collaborators (2009) suggest, so can the obsessive need to classify and to make systems. He developed the hyper-systemising theory (2009) in which he argues that an ultimate understanding of systems follows from the acute attention to detail and leads to the development of talent in that area (Baron-Cohen et al., 2009).

In the last two decades, the savant phenomenon has become much more visible to the general public through the use of the internet, with many savants showcasing their work through their own websites, and video sites such as

YouTube. DP has his own website and so do other savants such as Stephen Wiltshire. YouTube has hundreds of videos of musical savants. On-screen data suggest that this facility has provoked many people to watch and listen, and to record their impressions in words, allowing an insight into general public awareness and understanding of savants. Reading all the comments, gives us one view of what the general public think, understanding how and at what level they are aware of the existence of savants, their desire perhaps to comprehend and to find an explanation for such advanced ability in the context of special needs. But, even at a scientific level, there are many unanswered questions.

To conclude, although informal criteria have been developed to define savantism, each researcher has tended to use different approaches to recognising savantism, ranging from anecdotal reports in the early years, to more comprehensive experiments and standardised and non-standardised tests (although many of these are not specific to savant syndrome, but to learning difficulties and autism in general). For example, Miller employed an empirical approach, whereas Treffert, like Sacks, relied on his professional observations of patients. In contrast, Ockelford used his teaching and musical expertise to describe savant's abilities in this field from an applied musicological point of view (Ockelford, 2012). The concept of exceptionality and learning disability will be explored in depth in later chapters.

2.3.4 Aetiology of savant skills

In the last fifty years many researchers have conducted studies in order to have a better understanding of the causes and origins of savantism. Each of these has offered different explanations according to the research method used and resultant data, and described the savants' development and skills, such as memory feats, music, art, maths and other creative arenas in which savants excel. Within these, there are various studies regarding the aetiology of savant syndrome.

In 2001, Clark collated research literatures of all notable experts in the field of savantism. He analysed the different aetiology process described by each author in their work, and then proceeded to differentiate savant skills according to specific causes.

The categories that he identified and the research pertaining to them (including that undertaken since Clark's 2001 paper) are as follows:

- *Domain-specific skills* (Owens and Grimm, 1941; Feldman, 1988; 1993; Scheerer, Rothman and Goldstein, 1945; Gardner, 1983; O'Connor, Cowan and Samella, 2000; Sacks, 1985; Spitz, 1995; Treffert, 1989; Treffert and Christensen, 2005; Heaton and Wallace, 2004; Mottron et al., 2013);
- *Early onset of skills* (Miller, 1989; Rimland, 1978; Rosen, 1981; Selfe, 1978; Young, 1995; Mottron and Belleville, 1995; Nettelbeck, 1999; Treffert, 2010);
- *Evidence of genetic link, similar interest/talent/gifts in families of savants* (Brink, 1980; Howe, 1990, 1998; Hermelin and O'Connor, 1990b; Rimland, 1978; Young, 1995);
- *Practice, skills developed through concentration and practice* (Anastasi and Levee, 1960; Ericsson and Faivre, 1988; Hoffman and Reeves, 1979; Howe, 1989; Miller, 1989; Treffert, 1989; Young, 1995; Treffert, 2010); Nadia (Selfe, 1978; 2011) and *reported loss of skills on cessation of practice*;
- *Motivation, obsessive interest/drive in savant activities* (Charness, Clifton and MacDonald, 1988; Treffert, 1989; Nettlebeck and Young, 1999; Frith, 1989; Ockelford, 2007a; 2012; 2013);
- *Executive functioning – weak central coherence* (Pring, Hermelin and Heavey, 1995; Pring, 2005b; Happé and Frith, 2010; Brunsdon and Happé, 2013), *skills independent from executive functioning and reliant on long term memory* (Nettlebeck and Young, 1999); *low level processing* (Frith,

1989; Happé, 1995; Snyder and Thomas, 1997; Snyder and Mitchell, 1999; Happé and Frith, 2010);

- *Pathological events/neurological and functioning – savant skills result from the formation of exceptional neural structures during prenatal brain development* (Treffert, 1989; Fein and Obler, 1988; Snyder, 2009).

All of these aspects may be considered as important in the difficult task of understanding and defining savantism; subsequent research and a literature review, (Pring et al., 1995 and Pring, 2010 – see above), describes a 'segmentation strategy', an information processing style that is thought to be a precursor to savant skills in which single representations are retained in the form of stable enduring wholes. Furthermore, earlier research by Snyder and Mitchell (1999) disputed that savants have low levels of information processing. In addition, Heaton and Wallace (2004) argue that, in order to explore the parameters of savantism, it is important to consider these skills within the context of neuropsychological accounts of autism.

Baron Cohen and Cross (2007) proposed that one of the causes of savantism could be a possible connection between the co-occurrence of synesthesia and obsessive tendencies. This research has been supported by a recent study conducted by Simner, Mayo and Spiller (2009) suggesting that visuo-spatial synesthesia could be the basis on which repetitive and obsessive habits contribute to the generation of savant-like abilities.

Taking all the various studies into account, it would seem logical to assume that there is a mixture of aetiological factors, such that quite often there is not just one reason, but multiple factors that contribute to an individual's savantism. We can find examples of different factors, such as pathological events that modify neurological functioning, in addition to an obsessive interest that drives the young or proto-savant to spend hours and hours focused on the same task. Also, it is assumed that this neurological functioning could lead to the obsessive interest.

Not all savants have the same level of prodigious ability, nor are the same aetiological factors implicated; they are hypothesised as being located on a continuum (Ockelford, 2008). Since the definition of savant is ambiguous, we cannot quantify the evaluation of savants' ability because our knowledge of the ability itself is subjective. However, this is not the only concern: even if we were able to quantify the degree of an exceptional ability, there is still a need to recognise and acknowledge that each savant is a unique individual.

The compromise between an absolute definition and no definition at all is to use an umbrella term such as savantism which is seen to contain all savants at different levels of ability and need: in another words at different points on the continuum, or perhaps continua. Such a conceptualisation would and should not stigmatise them, but we should evaluate their inter-individual differences under such an umbrella term. In addition, this could help in many ways by providing a better understanding of the powers that their ability yields; thus perhaps enabling us to provide better support and giving them the possibility to develop and lead more fulfilled lives. Further explanations about different savant's profile and abilities will be provided in Chapters 3, 4 and 5.

2.4 Pitch perception: absolute pitch (AP)

Pitch is a dimension of auditory sensation that permits sounds to be perceived as being ordered on a scale ranging from low to high (Lewis, 1939). In 1960 The American Standards Association defined pitch as 'that attribute of auditory sensation in terms of which sounds maybe ordered on a musical scale'. The physical correlate of pitch is frequency (Stevens, Volkman and Newman, 1937).

Absolute pitch (AP), referred to by musicians as 'perfect pitch', is the ability to identify or produce the pitch of a sound without any reference point (Baggaley, 1974). It has been reported to be present in 1 over 10,000 people (Takeushi and Hulse, 1993) and in 1 in 20 musicians (Hamilton, Pascual-Leone and Schlaug, 2004). A survey carried out by Welch (1988) indicated that in 34 congenitally blind children, 22 possessed AP (65%). A related study by Ockelford (1988), suggested that a number of these children were on the autism spectrum.

The acquisition of AP is typically automatic and non-conscious and likened to the acquisition of language (Deutsch, Henthorn and Dolson, 2004). Sergeant and Vraka (2014) described an AP listener as having the ability to have: pitch recognition, key recognition and pitch production.

Zatorre (2003) and Levitin and Rogers (2005) suggested two sequential processing phases contributing to the development of AP: pitch memory and pitch labelling. Pitch memory is referring to a perceptual pitch encoding, while pitch labelling is a more cognitive process reflecting an associative memory. Ockelford (2008) points out that pitch labelling is not necessary in AP (since many autistic children with AP cannot name notes). Elmer et al. (2013) re-evaluating the 'two component' model of AP indicate that associative memory representations are crucial psychological processes for AP possessors.

2.4.1 AP and chordal disaggregation among people on the autism spectrum and savants

AP is prevalent among children with autism (at least 5%) indicating that AP could be associated with some of the peculiar cognitive and social features of the autism spectrum disorder (Brown et al., 2003). In addition, pitch memory and (sometimes) pitch labelling are superior and are linked to special musical abilities that facilitate performance in musical tasks (Heaton, 2003). In fact, AP is almost invariably a factor in the manifestation of precocious musicality in children with autism (Ockelford, 2013). *All* cases of musical savants described in literature possess AP (Rimland and Fein, 1988; Treffert, 1989), and research on musical savants shows that both pitch memory and pitch reproduction are exceptionally highly developed (see, e.g., Ockelford and Pring, 2005). A study on AP and the disaggregation of chords involving two savants and a 'neurotypical' musician (Ockelford, 2008; Pring, 2010) is described in detail below. This study underpins the research with a larger sample that is presented in Chapter 3.

The first written account of the disaggregation of chords date backs to 'Blind Tom', the American savant. In the *Manchester Courier* of 26th September 1866, it was reported that when he participated in an informal musical experiment to verify his capacity to analyse chords, he was able to name the notes in the chords that were played to him correctly. It should be pointed out that the capacity to disaggregate chords is not confined to musical savants; some 'neurotypical' musicians also have this ability. A case study of Erwin, a musical prodigy (Revesz, 1924/1971), reports his high level of musical skills and his excellent capacity to disaggregate chords. Erwin is the exception rather than the rule, however: Huron (2001) and Ockelford (2012) report that most people without advanced musical training find it difficult to distinguish between more than two or three notes simultaneously.

Research into the disaggregation of chords undertaken by Charness et al. (1988), Miller (1989), which used four simultaneous pitches, did not considered the *strategies* utilised to perform the task. However preliminary work conducted by Ockelford (2008) described the performances of DP, another savant and one comparison subject, examining their ability to disaggregate chords and the possible strategies they were employing.

Ockelford (op. cit.) measured one of the features of AP ability by having these three subjects (including DP) identify the individual pitches in complex note clusters (chords) through reproduction. This task has challenging as the musical material was merged into sonic wholes (chords), forming Gestalts that by definition are very difficult to deconstruct into their elements (Pring, 2010). DP and the other participants were asked to reproduce 120 chords (divided in groups of 20) varying in size from 4–9 notes, played on a piano. A 'listen and play' protocol was applied (as in Charness and Miller, op. cit. – necessary due to the limited musical metacognitive capacities of the savants), and the numbers of notes correctly reproduced were counted, and taken as a proportion of the total size of each chordal stimulus. DP showed evidence of an exceptionally detailed perceptual representation derived from the sensory stimulus and one that afforded an immediate translation into fingering (Pring, 2010, p. 221). Pring (op. cit.) argues that it is not clear if this outstanding achievement should be attributable to a reflection of long-term memory knowledge representation or a short-term memory capacity (episodically-based) for domain-specific material. Hence, there is a further need to explore systematically and extensively this challenging topic with larger populations of savants and 'neurotypical' musicians with AP.

2.5 Learning and memory for words and music

Several of the main theories of memory (outlined below) have been influenced by Bartlett's *Remembering* (1932), which focuses on the retention and recall of meaningful verbal material. In one of Bartlett's experiments, subjects were asked to listen to and then recall a story. He found that, instead of reproducing the story exactly, participants used a process of reconstruction, based on their experiences and feelings, as well as their own prejudices and stereotypes. The studies suggested that participants add their own meaning when they recall a text. Bartlett named this concept 'effort after meaning'. In his view, personal experiences play a significant role in how information is encoded, stored and subsequently retrieved. He argued that memories lead to the creation of 'schemas': internal representations through which our knowledge of the world is structured, and which have an impact on the way that new information is stored and later recalled.

Kay, in 1955, inspired by Bartlett's studies (1932) on the unreliability of memory and the inaccuracy of reproduction, focused his research on the persistent errors made by participants whilst repeating a verbal stimulus that they had been asked to learn. He found that, having created their own personal version of a story, participants found it difficult to depart from this erroneous account in subsequent recall attempts. He measured the closeness between participants' first reproduction of the story and the original, and undertook content and repetition analyses of their responses. His findings suggested that, on the first attempt at recalling the story, participants remembered the general content and meaning well (70% correct), but were less accurate in terms of actual words used (30% correct). Participants' subsequent attempts were similar to each other and to their first reproduction in both content and verbal analyses. Moreover, subjects had the tendency to repeat verbal or conceptual mistakes from their first attempt in subsequent recollections, demonstrating the difficulty of unlearning their own mistakes.

The literature frequently divides memory into different components based on the length of time for which information is stored, and how it is processed (Miller, 1956; Baddeley, 1966). Short-term memory (STM) is used when immediate access to information is needed. The size of the short term 'store' (the number of items that one is able to recall) was found by Miller (1956) to be the 'magic' number 7: one is able to remember 7±2 items. STM in the auditory domain is based on the acoustic representation of information (Baddeley, 1966); conversely material held in long-term memory (LTM) is primarily stored in terms of meaning. Rehearsing information in the short-term store leads to better retention within STM, as well as increasing the probability of it being permanently stored in LTM.

Following Baddeley (1966) and Sperling (1963), Conrad and Hull (1964) reported that the participants in their memory study confused letters that sound similar, supporting previous evidence that the information in STM is encoded acoustically. The study detailed in Chapter 5 aims to explore further the differences in how information becomes encoded in STM and LTM by testing both types of memory for the same verbal stimulus, and analysing different elements of participants' responses, including acoustic qualities (sonance).

Memory can be further subdivided by the type of information retained, for example sensory memory (Sperling, 1963) and verbal memory (Glanzer, 1972). One of the first studies to be undertaken on sensory memory was conducted by Sperling in 1963. The sensory memory, rich in terms of its content, but very brief in duration, can be divided into echoic memory (for auditory information) and iconic memory (for visual information).

Across categories of memory, information is better retained from the beginning and end of any given stimulus. Postman and Phillips (1965) showed that there is a tendency for the first and last few items in a sequence to be better recalled, and termed these phenomena 'primacy' and 'recency' effects, respectively. Subsequently, Glanzer and Cunitz (1966) described the characteristics of STM and LTM in free recall, arguing that their subjects tended to remember better the beginning and end of a list of items, compared to words from the middle of the list.

In 1972, Tulving identified a type of remembering that he termed 'episodic' (EM). This comes into play for events that happened in the past, but that are also currently useful for daily life (for example remembering the differences between types of coin). EM is the only type of memory that enables people to re-experience past moments, and is argued to have developed from semantic memory, the latter being for facts that possess meaning (Tulving, 2002). Moreover, memory can have an impact on our emotions, thoughts and attitudes, although sometimes we are not conscious of this, as these memories can be involuntary.

There are many variables that need to be taken into consideration when assessing memory. First, it can be studied in everyday life or in artificial settings (laboratories). In 1978, Ulric Neisser pointed out the disadvantages of the laboratory-based studies that followed the Ebbinghaus tradition, and proposed more ecologically oriented research. It was recognised that controlled laboratory conditions allowed testing and development of theories, and that the accurate replication possible in a laboratory can benefit the generalisability of the results. However, a more ecological approach can lead to findings that are not discernable in a laboratory, due to the artificial conditions. Another advantage is that ecologically accurate experiments can confirm principles previously determined in a laboratory (Neisser, 1997). This should not lead to the avoidance of laboratory-based experiments, but both should be considered as giving valuable findings.

Many types of material can be used in memory experiments, such as lists of syllables, (following in Ebbinghaus' tradition), texts and stories, (Bartlett's tradition), poems and pictures. The content of each of these can also be varied. Neisser (1997), argued that the recollection of moments, events, thoughts and actions is related to their exclusivity (i.e. how frequently they occur) suggesting that memory depends most fully on the degree of arousal experienced when they are first encountered. Research on memory for words in poems and songs (Wallace and Rubin, 1988) demonstrated that the structure of these stimuli facilitates memory for the detail within them. Furthermore, it seems that memory representations of lyrics are connected to memory for melody (Crowder, Serafine and Repp, 1990), in particular rhyme, style and melodic emphasis.

In 1974, six years after Atkinson and Shiffrin (1968) proposed a model which distinguished between LTM, STM and sensory memory, Baddeley and Hitch introduced a working memory (WM) model in which STM is divided into three parts: the phonological loop, the central executive and the visuo-spatial sketchpad. The phonological loop consists of a phonological store and an articulatory control process; the visuo-spatial sketchpad is used for creating and manipulating mental images, whilst the central executive regulates attention and organises the other two systems. The main memory distinctions here are long-term, short-term and sensory memory. In 2000, Baddeley proposed a revised role for the episodic buffer, originally introduced in the Working Memory Model of 1986 as facilitating the assimilation and manipulation of material in working memory. He suggested it forms the foundation of our conscious awareness by combining information from different sources and experiences into organised 'episodes'. In 2003 he further extended the model to incorporate working memory in people with language disorders.

After Baddeley's work, Berz (1995), followed by Ockelford (2007), offered an extension of the Working Memory Model by proposing the existence of a music module responsible for the processing and storage of musical material. Ockelford suggests that the music module may be connected to the central executive (proposed by Baddeley, 1966) and therefore could be a component of it. This theory arose from findings gathered from an experiment conducted with an autistic savant (DP) who demonstrated the ability to hear, process, connect and remember musical material. However, more data are necessary to further evidence the existence of the music module, an issue that will be taken up in Chapter 5 of this thesis.

Compared with verbal memory, research into memory in music listening has occurred only relatively recently. The perceptual processes used in the comprehension of music appear to be much in line with those used for materials in other domains, although there are theories proposing that music is partly modularised in cognition and brain organisation (Pertez and Zatorre, 2005). In music cognition research episodic memory is typically tested using recognition or, more rarely, recall tasks. Semantic memory tests usually require participants to make judgements about which events are likely to occur in particular musical situations. This type of semantic memory is based on schemas, which provide general expectations about types and distributions of events in a given context (Bartlett, 1932; 1995; also see Gjerdingen, 1988, pp. 3–10).

Schemas appear to underlie structural regularities in music such as tonality and metre, as well as standardised musical forms. Ginsborg and Sloboda (2007) found that experienced singers better recalled words when they were linked to a melody. Musical schemas can be described in terms of 'implicit' memory (Kvavilashvili and Mandler, 2004) (as opposed to 'explicit' or 'declarative' memory), as they are involved in the unconscious generation of expectations about musical events as a piece develops. Making such schemas explicit is one of the goals of the formal study of music. Implicit perceptual memory is the basis for recognition of previously encountered stimuli, though many activities involving memory have both explicit and implicit components which are not easy to distinguish between in research.

Long-term schematic memories tend to be structured using generalised categories (MacAdams, 1989; Snyder, 2000). Musical long-term memories and expectations are thus often structured in terms of schemas such as scale-steps and durational classifications. This means that listeners tend not to have exact detailed memories of music, but more generalised memories about the kinds of events that were heard; hence, a listener's repertoire of categories of musical events (knowledge in memory) will affect what they can and do remember. There are also other forms of working memory, for instance for motor movements and non-speech sounds (Smith and Jonides, 1997).

It seems that memory networks established by an original stimulus may remain below the level of consciousness but can nonetheless affect ongoing thought and perception, providing a basis for expectation. An expectation is generated by a group of networks (a schema) that have been primed by current experience. The concept of expectation is important here because it is a primary mode through which people use memory in listening to music, and because it is thought to be one of the sources of emotional response to music (Meyer 1956; Huron 2006). Ockelford and Sergeant (2013) found that participants exposed to serialist music came to expect the lack of tonal repetition which is characteristic of this style, but were still influenced by tonal schemata when making judgements about how well a probe tone fitted into a given context. A summary of expectation research is to be found in Grundy and Ockelford (2014), which explores the role of between-groups musical expectations for a musical savant who was asked to play along with a novel piece of music.

2.5.1 Learning and memory in autism and savantism

In this section, research on memory abilities in people with ASD, including musical savants, will be examined. One of the main characteristics of autistic savants is the outstanding memory that they demonstrate in various areas, such as music (musical savants: see, for example, Hermelin and O'Connor, 1987; Miller, 1998; Heaton and Wallace, 2004), photographic memory of landscapes and objects (artistic savants: see, for instance, Howe and Smith, 1988; Selfe, 2011), numbers (calendrical savants: see Young and Nettelback, 1994; Cowan et al., 2003) and auditory verbal memory (Stevens and Moffitt, 1988). Savants have also been shown to demonstrate exceptional memory for lists of words (Hill, 1978), 'rote memory' (high fidelity representation of the original information, involving little reorganisation and thought to be related to the physical aspects of a stimulus: Miller, 1999) and semantically organised memory schemata (Pring and Hermelin, 1993). Memory for the information in the above categories has been shown to be long term (Rosen, 1981; Hermelin and O'Connor, 1987).

Understanding of savants' memory has evolved over the last forty years; Hill (1978) described savants' memory solely as a form of rote memory, meaning a recall of information as opposed to 'logical' memory, in which the memorised material is closely related to mental concepts. A variety of experiments have been undertaken in order to better understand the memory capacities of savants. These have suggested both similarities and differences in the ways that savants and non-savants process various stimuli. Research undertaken by Spitz and La Fontaine (1973), Hill (1975) and Young and Nettelback (1994) reported no differences between the digit spans of savant and control participants. On the other hand, Kehrer (1992) found that the perception and storage of information function differently in savants compared to 'neurotypical' people, underlining also the differences in memory functioning. In accordance with the previous findings, Mottron et al. (1998) suggested that the exceptional episodic memory demonstrated by some savants could be related to an atypical resistance to interference, and differs both quantitatively and qualitatively from that of 'neurotypical' people, although further research is required to assess how far these results can be generalised. Valentine and Wilding (1994) carried out a memory experiment in which savants and non-savants were asked to recall verbal stimuli and phone numbers. Two of the savant participants reached between 20% and 40% accuracy in the verbal experiment, whilst they scored 100% for the recall of phone numbers. This suggests that both savants processed the stimuli differently from the non-savant participants. With regard to declarative memory, savants do not demonstrate superior performance; however calendrical savants exhibit better mnemonic functioning for tasks involving dates (Heavey, Pring and Hermelin, 1999). Hence it seems that savants' outstanding memory performances are associated with their specific exceptional abilities (in this case, for recall of numbers). The detail-focused information processing that is described by Happé (1999) as a characteristic of those with ASD has been evidenced in the savant population. Savants have been shown to have superior non-cognitive memory, named also 'habit' memory (Young, 2005), in restricted areas. The development of these aspects of memory is fundamental to savant skills.

Hermelin (2001) used the term 'splinter skills' to describe exceptional peaks within a general spread of abilities. More recently this term has been criticised as too being generic and has been replaced by the terms 'domain-specific skills' and 'domain-general skills' (Heaton and Wallace, 2004). Savant abilities could be described as domain-specific, as this term refers to skills that are particular to one field. Domain-general skills are transferable across a range of areas within an individual's cognitive profile. In 2004, Heaton and Wallace discussed the concept of domain-specific abilities as being more appropriate than rote memory to describe the nature and characteristics of savant skills. They demonstrated that savants' extensive memory and knowledge of music and art are not gained just through repetition, but require an understanding of and an ability to elaborate on information. The term 'domain-specific', as Heaton and Wallace discuss, highlights the particular nature of the material involved, taking into consideration the general cognitive profile of the individual.

The high variation in the level of intellectual functioning within the autistic population must be taken into consideration. Obtaining high or low scores in any particular test or experiment could be the result of differing levels of cognitive ability (such as attention and learning) rather than a characteristic of ASD (Heaton and Wallace, 2004). Hence, when reporting the findings, it is important to note that the results obtained from one group of autistic participants may not be applicable to everyone who comes under the ASD umbrella.

Mottron et al. (2006) introduced the model of 'enhanced perceptual processing', which suggests that the over-functioning of parts of the brain related to perception may explain savant abilities. This enhanced perceptual processing applies also to heightened pattern detection (Mottron et al., 2009) across diverse domains that are highly structured, such as numbers, letters and musical notes. It is argued that the overall organisation of these systems facilitates detection of and memory for the specific content, allowing the development of savant skills.

Mottron et al. (2013) developed this argument by highlighting the dimension-specific nature of savant perceptual abilities (also reported in some people with autism). According to Bennet and Heaton (2012), special skills are associated with superior working memory coupled with highly focused attention, helping to explain the link that savants show between a general intellectual impairment and exceptional domain-specific abilities.

Mottron et al. (2013) state that this enhancement of perception leads to an exceptional ability to detect patterns. He suggests that this stems from enhanced awareness of and veridical memory for similarities between patterns, both within and across perceptual modalities. Within domain-general abilities, autistic people sometimes show ‘dimension-specific’ abilities; these are skills that cut across different domains. However, savant abilities are usually domain-specific (Mottron et al., 2013).

Research has demonstrated atypical auditory processing in people on the autism spectrum (Happé and Frith, 2006; Samson et al., 2006). Järvinen-Pasley and Heaton (2007) asked participants (children with autism, and controls matched for chronological age, and verbal and non-verbal intelligence) to discriminate between pitches in both musical and speech stimuli. Within the ASD group, no differences by type of stimulus were found, suggesting that children with autism show similar sensitivity to pitch in both speech and non-speech stimuli. The control participants performed better for the musical stimuli than the speech. These findings indicate that auditory processing is less domain-specific in autism than in typical development, with a processing bias towards low-level information.

A subsequent experiment was carried out by Järvinen-Pasley et al. (2007) in which linguistic stimuli containing both low-level perceptual information and high-level semantic information were played to both autistic and ‘neurotypical’ participants. Findings showed that children with autism displayed superior perceptual processing of speech compared to the ‘neurotypical’ participants, whilst the latter group exhibited a tendency to process speech semantically. In line with these results, Heaton et al. (2008) found that the performance of an autistic subject who was asked to name and remember the pitches of a speech stimulus was superior to control participants' attempts at the same task. This confirms the results of Järvinen-Pasley and Heaton (2007), showing that auditory processing is less domain-specific in people with ASD than the wider population.

In 2005 Ockelford started a series of studies focusing on the abilities of musical savants within a project called REMUS ('Researching Exceptional MUsical Skill'), which seeks to explore learning and memory in savants in four conditions. These were:

1. 'Listen and play' (Ockelford, 2005; 2008; 2012)
2. 'A bit at a time'
3. 'Play along' (Grundy and Ockelford, 2014)
4. 'Just listen'

This project (REMUS) is currently incomplete because he has not yet looked at all the ways in which savants learn pieces – for example, learning 'a bit at a time'. The second study of this thesis will endeavour to explore this condition, in order to understand more about this strategy and its implications for learning and memory in DP (and savants more widely).

The REMUS data were fundamental to Ockelford's hypothesis of the existence of a music module in working memory (Ockelford, 2007), evidenced by the analysis of DP's performance of a piece of music which he had heard and been asked to play back. Pring (2010) reported that savants demonstrate a specific way of thinking about and processing material, and suggested that their restricted and particular interests could predispose them to create complex knowledge structures for those areas in their long-term memory. This could explain the presence of outstanding (though constrained) memory abilities in the savant population.

2.6 Conclusion and research questions

This chapter opened by setting out the nature of autism, as defined in relation to the seminal work of Asperger (1938), Kanner (1944) and Frith (1989), and more recent studies. It was noted that a variety of characteristics identified by these researchers as 'autistic traits' have been found to be shared by savants, such as restricted areas of interest, stereotypical behaviours, echolalia and special abilities.

A brief history of the savant phenomenon was presented, noting the various researchers who have contributed to the field, starting with Down (1887) and more recently Hill (1974) and Rimland (1978). It was observed that the nature of this research has changed from the early anecdotal accounts to more formal studies (Miller, 1989; Ockelford, 2008; 2012). Inevitably, research has often been based on case studies because of the small size and heterogeneous nature of the savant population, and, as Ockelford (2013, p. 239) points out, there remains a bias towards theorising based on unsubstantiated anecdotal evidence ('Leslie's story', Treffert, 1989). However, Happé and Frith (2010), Happé and Vital (2009), Pring et al. (1995; 2012), Baron-Cohen et al. (2009), Heaton et al. (2008) and Ockelford (2012; 2013) have devised psychologically-based tools that have allowed the scientific community a clearer view of the underlying cognitive processing methods of those with autism, including savants.

In the light of this critical review of the literature, my research interest was to explore aspects of savant musical behaviours more deeply. This work is intended to form part of a move towards greater rigour in savant research, exploring in detail the psychological processing of musical savants, analysing their perceptual and cognitive (in particular, learning and memory) abilities through both observations and experiments.

Perception

Given that musical savants have AP and an ability to disaggregate chords:

1) To what extent and in what ways are the chordal disaggregation abilities and strategies displayed by DP typical of other savants and 'neurotypical' musicians with AP? Specifically:

    1a) What are savants' capacities for disaggregating chords (including simple and higher diatonic combinations of notes, chromatic composites, and clusters which have no tonal implications)?

    1b) What is the impact of chordal size, structure and complexity on savants' perception of them?

    1c) Is it possible to identify particular strategies that savants may use for disaggregating chords?

    1d) Do these strategies differ from those used by 'neurotypical' musicians with AP, and if so, in what ways?

This is addressed in Chapter 3.

Learning and memory in music

Given that savants typically learn pieces intuitively, by listening and playing:

2) To what extent and in what ways is DP's capacity to learn music by ear affected by the mode of presentation? Specifically:

    2a) What impact (if any) does the (enforced) strategy of breaking a memorisation task down into small chunks and learning 'a bit at a time' have on DP's learning and recall (compared with learning a piece 'all the way through')?

This is addressed in Chapter 4.

Learning and memory in verbal material

In order to further clarify domain-specificity and the possible existence of a music module in working memory:

3) To what extent and in what ways is DP's capacity to learn and recall music domain-specific: in particular, how does it compare with his ability to learn and recall verbal material? Specifically:

> 3a) How do DP's verbal memorisation abilities compare with those of another savant and 'neurotypical' musicians with AP?

This is addressed in Chapter 5.

CHAPTER 3: AP STUDY

3.1 Introduction

The current research explores the nature of savant abilities using specific musical tasks. In this section, consideration of the pitch perceptual abilities of musical savants will be examined using data from a specially designed experiment. Based on the assumption that all musical savants possess absolute pitch and can disaggregate chords (Charness, Clifton and MacDonald, 1988; Miller, 1989; Obler and Fein, 1988) it is of interest to explore this capacity further, and investigate how they are able to disaggregate different sizes and types of chords by perceiving their constituent notes.

3.2 Aims and questions

In order to investigate the 'disaggregation of chords' phenomenon more thoroughly, a protocol used by Ockelford (2008) has been adapted for this research. Here, a sequence of diverse chords is used (chords are defined as two or more notes played simultaneously). The experiment employs different types of chords: tonal (diatonic and chromatic) and 'cluster'. A cluster is a type of chord that does not conform to 'common practice' in Western harmony.

The question that arises is whether all savants disaggregate chords using similar strategies and to a similar level of accuracy or whether there are differences between individuals. Do they process 'tonal' and 'non-tonal' chords equally effectively? How do these strategies compare with those of advanced 'non-savant' musicians? To find answers to the above issues, the following questions and sub-questions were formulated with reference to music perception. The research reported in this chapter addresses Research Question 1:

Perception

Given that musical savants have AP and an ability to disaggregate chords:

1) To what extent and in what ways are the chordal disaggregation abilities and strategies displayed by DP typical of other savants and 'neurotypical' musicians with AP? Specifically:

    1a) What are savants' capacities for disaggregating chords (including simple and higher diatonic combinations of notes, chromatic composites, and clusters which have no tonal implications)?

    1b) What is the impact of chordal size, structure and complexity on savants' perception of them?

    1c) Is it possible to identify particular strategies that savants may use for disaggregating chords?

    1d) Do these strategies differ from those used by 'neurotypical' musicians with AP, and if so, in what ways?

3.3 Method: chords disaggregation test

3.3.1 Selection of participants

Six savants and 17 comparison subjects participated in this experimental study. The latter were music students with AP, skilled pianists and able to play fluently by ear. The savant participants were recruited through networking in the field of visual impairment, autism and learning disability – in particular through contacts of my supervisors (one participant was recruited from Italy, and the others from the UK). Italian neurotypical participants were selected via an academic contact at the Pavia Conservatoire, who asked students who were known to have AP and to be fluent pianists, used to playing by ear, if they wished to participate in the study. English participants were recruited via an advertisement placed at the Royal Academy of Music in London, inviting students who had AP and were capable pianists who could play by ear if they wished to participate.

The study uses a perception test of absolute pitch abilities specifically to gauge their capacity to disaggregate chords. It is unlike previous studies that used a single case study (Charness et al., 1988) or studies (Ockelford, 2008). The current study, like that of Miller (1989), includes 6 savants, with the intention of acquiring a deeper understanding of their musical abilities and behaviours. The 17 comparison participants are also involved to enable a comprehensive description of these musical skills within a population of advanced 'neurotypical' Western musicians.

Although six subjects may appear a small number in the context of music perception research in 'neurotypical' populations, in terms of prodigious savants, it represents a much greater proportion (see Chapter 2). Having a larger comparison group (17 participants) enables a conceivably broadly representative sample of advanced Western classical musicians with AP to participate in the chord disaggregation experiment.

In the following paragraphs, biographies of DP and GN will be provided, alongside a description of the sources from which this information was taken. Detailed information about these participants has been provided because, unlike the other savants, they took part in more than one study within this research (see Chapters 4 and 5). Participant initials instead of full names are used throughout the study for confidentiality purposes.

3.3.2 Sources of the information about DP

Sources of biographical information for the case study of DP are the published literature about him (Ockelford, 2007a; 2008), observations, and interviews with key people in his life, such as his carers and his music tutor Professor Adam Ockelford (AO).

The initial meeting with DP arose as part of a psychology of music lecture programme at the Institute of Education. DP and AO were invited speakers. DP was introduced as a talented pianist with great improvisational skills and the ability to play by ear. The opportunity arose to interview AO regarding his work with DP, and he then invited me to come and meet DP; this subsequently led to a meeting with DP's parents and his carers.

3.3.3 Information about DP

DP is blind due to retinopathy of prematurity, and was 30 years old at the time of the tests. Test results (provided by Clinical Psychologists) have repeatedly shown that DP has severe learning difficulties, with a verbal IQ of 58 as measured on the WAIS-R, and a diagnosis of autism (Ockelford and Pring, 2005). However, from an early age he acquired a fascination for music and sound, and by the time he was four, he had taught himself to play a large number of melodically and harmonically complex pieces on the piano. (Ockelford, 2007a).

When DP was five, his enormous musical potential was recognised by AO, then a music teacher at Linden Lodge School for the Blind in London. From that age, AO gave him weekly lessons, which subsequently progressed into a programme of daily sessions, a pattern of tuition that was to last for several years. Through meticulous physical demonstration and imitation, DP is reported to have acquired the foundations of technique that were necessary for him to become an accomplished performer (Ockelford, 2007a). AO taught DP how to place his hands on the keyboard correctly and how to maintain an appropriate posture whilst playing, as well as 'socially acceptable' conduct when appearing in public. He learned classical pieces, building an extensive repertoire, although his natural affinity for jazz, pop and light music soon became evident. He has always learnt all pieces by ear and today he is still a keen improviser (Ockelford, 2005).

Since the time of 'Blind Tom' (mentioned earlier) the media have propagated the suggestion made by those promoting savant abilities that all musical savants have 'perfect recall'; however, this is not the case. For example, AO reported that DP learns complex pieces through many repeated hearings and practice, and never reproduces them with 100% accuracy.

As noted above, in order for DP to learn a new piece of music, he usually has to listen to it several times and then play it. Once he has learned it correctly, DP is then able to play and retain it for a long time in his 'mental library' (at least four years; Ockelford, 2012, p. 187). It would appear that his absolute pitch ability is essential in his learning and recalling pieces (Ockelford, 2008).

At the time of the research, DP was a student at Redhill College in Surrey, England, run by the Royal National Institute of Blind People (RNIB). He attended courses at 'Soundscape', a unique performing arts centre for young adults with learning difficulties and exceptional musical abilities or needs.

The most important point is that music is perceived to connect DP to the outside world and to give him a sense of identity; music is an important source of shared meanings (Hargreaves and Marshall, 2003), especially for those whose language is impaired (Ockelford, 2012). Music helps DP to socialise: for example, he loves the applause that he generates in public performances; it really engages him with the wider world (Ockelford, 2007a).

3.3.4 Sources of the information about GN

When the research work began, none of the available literature sources mentioned savants of any description in Italy. One of the aims was therefore to see if there are any Italian musical savants. The term 'musical savant' is not often used in Italy to describe people such as DP; usually they are categorised as having autism spectrum disorder with high functioning ability, perhaps the reason for the lack of literature relating to savants. GN was brought to the attention of Professor Welch (GW), Professor of Music Education at Institute of Education, University of London (now UCL), who was presenting a seminar on music education at the University of Bologna, where he discussed DP and his history. Professor Anna Maria Bordin (AMB), GN's music teacher, attended this seminar and found a similarity in the life story of DP and GN, whom she taught at the Conservatoire of Pavia. AMB then contacted GW by email after the seminar wanting to know more about musical savants and explaining her experience with

GN. Email contact was established and, through this, a meeting between her and the current author was arranged in Pavia, Italy.
The aims of the doctoral research were discussed extensively and the conclusion was reached that it would be beneficial to involve GN as a participant in the research project. Hence, an introduction to GN and his parents was made by AMB. The protocol for the experiment was discussed informally and followed a similar pattern as for DP and the other musical savants involved in the research.

3.3.5 Information about GN

GN was born with a congenital neurological condition that meant he was partially sighted and, at the age of three, he was diagnosed using ADI-R (Rutter and Lord, 1994) and ADOS (Lord et al., 1989) with a form of autism spectrum disorder called high functioning autism (DSM, IV/Rev.; APA, 2000). Although he is partially sighted, his behaviour is comparable to a more severely visually impaired person in terms of mobility and orientation (Bordin, 2003).

His parents report that, at the age of two, he became fascinated with playing the piano. His cousin, who is a professional pianist, would play the piano for him and her passion for music is also evident in him. Then, when he was eight years old, he met his current music teacher, AMB, and began working with her.

At time of the research, GN was 18 years old and attending a high school in Milan, which specialises in ceramic arts, as well as a school for people with learning disabilities where pupils follow a behavioural programme called TEACCH (**T**reatment and **E**ducation of **A**utistic and related **C**ommunication-handicapped **CH**ildren).

In addition, GN attends the conservatoire in Pavia. Although the conservatoire, which has the status of a university, does not specialise in teaching young people with autism, AMB adopts strategies that are customised for him, such as making the lessons structured by telling him meticulously the order of the musical pieces that he should play. With regard to studying the history of music, she prepares a timeline in order to make the concept of time easier for him to understand.

GN has completed the eight-level piano examination of the Pavia Conservatoire, which involves, among other things, playing piano sonatas by Beethoven, preludes and fugues from Bach's Well-Tempered Clavier, and pieces from the Romantic repertoire. He has also taken harmony and history of music examinations.

From time to time, when he is playing, his parents observe that GN appears to go into his own private world, isolating himself from everyone and everything. Once he is in the 'moment of experience' with his music, nothing appears to distract him from it, like a 'flow' of consciousness (Csikszentmihalyi and Csikszentmihalyi, 1988).

For the past ten years, AMB, with the support of GN's parents, has established a pedagogical relationship with him, which includes teaching him to regulate his mood and actions and to discipline himself accordingly.

In conversation, AMB noted that it was not easy to teach GN to be precise in his performance, as he prefers to move on quickly to the next musical piece. At times, this has created frustration for him and AMB. Based on her observations, his relationship with the piano is focused on the rhythm, harmony, and micro and macro musical structures of the pieces he plays. In addition, AMB perceives that GN relates to music in a rational way, adopting a cognitive approach.

Methods of practising music have been very important for GN to learn, and through music education, he is reported to have transferred the 'repetitive skills' that he gained musically to other aspects of his life, such as eating with a fork, brushing his teeth, and tying his shoelaces. In other words, it appears that skills acquired through music have had a positive impact on other areas of GN's life.

GN's relationship with the keyboard, in terms of fingering, gesture and control, shows that he has studied the instrument formally, is proficient and has mastered many areas of technique. These skills enable him to perform in public.

3.4 Ethical procedure

3.4.1 Ethical procedure: savants

The ethical considerations in the research are particularly important with this group because of the issue of informed consent, and whether the savant participants were able to give it. With the savant group, the author and lead supervisor (AO) went through a long process to ascertain whether the savant participants really wished to participate in the experiment and that they were happy to do all that it involved. The Ethical Guidelines that were produced for DP and the agreed research protocol were used for each of the savant participants; a Criminal Records Bureau (CRB) clearance for the author was also obtained (see below). A letter was written to the parents, carers and/or advocates of the savants explaining the aims of the research and to seek permission to invite them as participants.

3.4.2 Ethical procedure: DP

In order to be able to undertake any work with vulnerable people such as DP, CRB clearance needed to be obtained. In addition, careful consideration of ethics was taken, and customised Ethical Guidelines produced (see Appendix I) that followed appropriate ethical procedures based on the 2008 British Educational Research Association (BERA) guidelines for people who are conducting research in the field of education, and also taking into consideration the most recent legal framework provided by the Mental Capacity Act (2005), designed to protect vulnerable people. The initial draft of the protocol for the research was discussed with the parents, advocates and carers of the savant participants.

The completed ethical guidelines were first approved by the research supervisors and then submitted to the Ethical Committee at the Institute of Education, which

authorised the research. Once the Institute of Education (IoE) Ethical Committee had sanctioned the research, a letter was written to DP's parents confirming the aims of the research to his advocates and seeking permission to involve DP as a participant for the research.
DP's advocates, carers and AO arranged a meeting to discuss the protocol of the research and the ethical guidelines in order to ascertain the impact this research might have on DP's life, if he should participate in it, and to seek permission to start to work with him. Finally, a letter was written to DP, phrased using language that he would understand. It was read to him in person by his tutor. The letter explained the intentions of the project and how his participation would be important to it. He readily agreed to participate.

The principles under which the research with DP was undertaken are detailed in the Ethical Guidelines, which can be found in Appendix I.

3.4.3 Ethical procedure: GN

Before I began working with GN, AMB explained to him in simple terms what the experiment was about, its purpose and how his participation could help people to have a better understanding of music and memory. She also made sure he was aware of how his schedule would change to accommodate the experiment, and how often and where he needed to complete the experimental task. A consent form was prepared in order to obtain formal and legal permission to conduct research with GN and to collect data. This agreement also contained the articles from the Italian Psychology Code of Practice, which governs research practices for collecting, using and disseminating data. As GN is of legal age, the consent form was read to him; he understood, agreed and signed it. The principles by which the research with GN was governed are included in the consent form that can be found in Appendix I. The recruitment of the other savant participants followed comparable procedures to those used with DP and GN.

3.4.4 Ethical procedure: comparison participants

Each 'neurotypical' participant had to complete and sign a consent form agreeing to participate in the experiment. They were also advised that they could withdraw from the experiment at any time if they should wish to do so.

3.5 Absolute pitch task: disaggregating chords

3.5.1 Introduction

Overall, 120 absolute pitch tests were conducted with 23 participants to measure the pitch perception abilities of savants and non-savants (see 3.5.4). As the group is heterogeneous (savants and non-savants), it is not expected that all subjects would necessarily use the same strategies or obtain similar levels of accuracy. However, anecdotal evidence (Revesz, 1924/1971; Stumpf, 1883/2003) suggests that musicians with AP would have at least some success with the task.

Chordal disaggregation does not necessarily imply an advanced AP ability, since non-AP possessors can also perform this task, although less successfully (Miller, 1989). However, the test described here can be conceived as an 'absolute pitch test plus', i.e. the capacity to separate chords into parts and recognise their constituent notes.

The rationale of this test is to measure participants' degrees of ability in disaggregating chords and to ascertain the number of simultaneous notes that they are capable of perceiving as separate units in a range of harmonic contexts. Also, the intention is to establish participants' strategies in performing this task, by measuring which notes in the chord are recalled most accurately – top, inner or bottom and test different types of chord (tonal or non-tonal). Furthermore, the task seeks to measure any differences between the disaggregation abilities of savants and non-savants and to discover whether participants consistently apply the same strategies for recall of notes throughout the task.

3.5.2 Procedures

The experiment uses a 'listen and play' procedure (see below) after Charness et al. (1988) and Miller (1989). This method is adopted because the savants cannot necessarily name pitches that they hear, even though they can recognise them. Therefore, the 'listen and play' procedure is an applicable method for all the participants (since the 'neurotypical' musicians can do it too). There are a total of 120 chordal stimuli: 20 chords composed of four notes, 20 of five, 20 of six, 20 of seven, 20 of eight, and 20 of nine (see Figure 3.1). This protocol was designed for this experiment and used by each participant.

The stimuli were played at a comfortable loudness level in a quiet environment using a professional music software programme and two 'M Studio' speakers connected to a computer. The participants completed the task individually. They listened to each chord in turn and replicated it as precisely as they could. The same equipment was used for all participants. A break was offered after every set of 20 chords; some participants accepted, others declined.

3.5.3 Stimuli description

The chordal disaggregation tests were custom-designed by AO in discussion with the author. The stimuli are from four to nine notes in size. Specifically, the chords range from diatonic harmonies (3^{rds}, 4^{ths}, 5^{ths}, 6^{ths}, 7^{ths}, 9^{ths}, 11^{ths}, 13^{ths} with a variety of chromatic pitches) to polytonal aggregates reminiscent of those used in Stravinksy's *Rite of Spring.* There are also 'clusters', collections of major and minor 2^{nds} that to most people would seem to be little more than noise (see Figure 3.1; Ockelford, 2008, p. 218). In Figure 3.1 (and those that follow) the first number above the bar represents the size of the chord (from four to nine notes); each chord group is numbered sequentially from 1 to 20.

The original stimuli were created using Sibelius software; each stimulus is one second in length, separated by a nine second pause before the next chord in the sequence is added. All the chords are played using a 'grand-piano' sound.

Fig. 3.1 Complete set of stimuli.

Fig. 3.1 Cont.

3.5.4 Participants

A total of twenty-three subjects participated (*cf.* 3.5.1); six savants (five male and one female) and seventeen (seven male and ten female) non-savant advanced musicians from the Royal Academy of Music (England) and the Pavia Conservatoire (Italy), who were used as a comparison subjects.

3.5.5 Equipment

The participants played a Korg SP-200 88-note, touch-sensitive, hammer-action keyboard. The chords they played were recorded digitally using a laptop computer connected to the keyboard via a MIDI (M-Audio MidiSport Uno – 1-

in/1-out – USB/MIDI) interface, monitored through M-AUDIO StudioPro 3 speakers. The MIDI data were captured using Cockos' Reaper Audio-MIDI workstation software, with technical support provided to the author by Dr Evangelos Himonides at IOE, for the translation of the proprietary Reaper files to standardised MIDI event data.

Sibelius version 5 music software was used to show participants' responses as musical notation. An audio recording was also made, using the Audacity programme. This programme acted as a backup device to the main recording procedure.

3.5.6 Location

The savant subjects undertook the experiment at their homes, at Soundscape or at Linden Lodge (a residential school) in London. The British comparison subjects performed their test at Roehampton University; for the Italian savant and non-savants, the experiment was conducted at the Pavia Conservatoire, in Pavia (Italy). Although the experiment was conducted in different locations, the same procedure was followed throughout.

3.5.7 Method of analysis

When the experiment was completed, the recorded Cockos' Reaper data files were translated into Standard MIDI Files (SMF), so that they could automatically be imported to the notation software (Sibelius v. 5) used for the analyses (see Figure 3.2).

Each set of data is 'cleaned up', as the representation of the non-quantised real MIDI data that are captured do not give a clear visual representation of the speed with which participants respond; also some notes do not 'switch off', and these are subsequently ignored (see Figure 3.2). By editing the MIDI file, the data are meaningfully represented in the notation software and rationalised temporally (see Figure 3.3). If participants played notes at different times, they are transcribed as a single simultaneous chord for ease of analysis.

After the rhythmic tidying-up was completed, scoring was undertaken using spreadsheets with four columns to map data across chords and participants (See Table 3.1). In the first column the chromatic scale is set out (C, C#, D, D#, E, etc.), the second column displays the octave (ranging from the 2nd to the 5th on the keyboard, in order to cover all the notes that could possibly be played with two hands). In the third column, the stimulus (the chord that the subjects listened to), is represented by an 'X' used to mark the notes within the chord. The fourth column represents the participant's response, marked in the boxes. This format is repeated 120 times. At the bottom of each column, the number of correct and incorrect notes from the top, inner and bottom of each chord are noted, and the total number of notes played by the participants reported (see Table 3.1).

Points are assigned to each chord, with the maximum possible score for each being equal to the number of notes within it (e.g. 4 for the chords made up of 4 notes, 5 for the chords made up of 5 notes and so on). These scores are then used to calculate the proportion of notes correct, relative to the total number of notes in the stimulus chord (and the number of notes played by the participant); see below for explanation of the methods used.

The scoring system is as follows:

- 1 point when the response is correct (the right note in the right octave);
- 0.5 point for the correct note in the wrong octave (since in one pitch dimension the response is correct and in another it is erroneous; Ockelford, 2012, p. 205);
- and 0 when the note is wholly incorrect.

In addition, for each chord, the number of notes that the subjects played is counted (see Table 3.1). Subsequently, the points scored for each chord are totalled and an Excel file is used to calculate the average score and percentage accuracy for each group of chords per participant. A probability score, based on a formula that takes into account the size of the chord and how many notes the participant played (explained below) was created to calculate the probability that the notes were played by chance. These probability scores are used to determine and differentiate the significance of the data and are included in the Excel chart (see Table 3.2). The weighted number shown in Table 3.2 is obtained by multiplying the percentage of notes that are correct (raw score) by: one minus the probability index.

The investigation also includes a more detailed analysis taking into account the size and complexity of the chords, and whether they were tonal or non-tonal; in addition the accuracy scores that the participants achieved for the top, inner and bottom pitches within the chords are recorded.

Fig. 3.2 Musical data recorded by Sibelius programme translated into Standard MIDI Files (SMF).

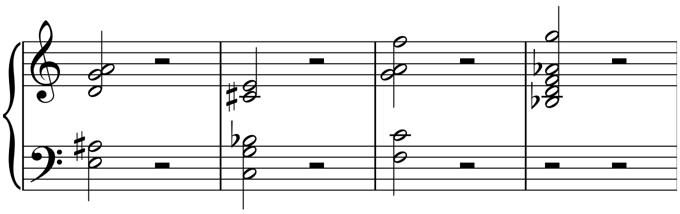


Fig. 3.3 Musical Data transcribed for analysis.

Table 3.1 Spreadsheets created to map data across chords and participants.

Chord number 5.6		Stimulus	Response		Chord number 5.7		Stimulus	Response		Chord number 5.8		Stimulus	Response		Chord number 5.9		Stimulus	Response
Notes	Octave no.				Notes	Octave no.				Notes	Octave no.				Notes	Octave no.		
A	5				A	5				A	5				A	5		
Ab/G#	5				Ab/G#	5				Ab/G#	5				Ab/G#	5		
G	5				G	5				G	5				G	5	X	X
Gb/F#	5				Gb/F#	5				Gb/F#	5				Gb/F#	5		
F	5				F	5				F	5	X	X		F	5		
E	5				E	5				E	5				E	5		
Eb/D#	5				Eb/D#	5				Eb/D#	5				Eb/D#	5		
D	5				D	5				D	5				D	5		
Db/C#	5				Db/C#	5				Db/C#	5				Db/C#	5		
C	5				C	5				C	5				C	5		
B	4				B	4				B	4				B	4		
Bb/A#	4				Bb/A#	4				Bb/A#	4				Bb/A#	4		
A	4	X	X		A	4				A	4	X	X		A	4		
Ab/G#	4		X		Ab/G#	4				Ab/G#	4				Ab/G#	4	X	X
G	4				G	4				G	4	X	X		G	4		
Gb/F#	4				Gb/F#	4				Gb/F#	4				Gb/F#	4		
F	4				F	4				F	4				F	4	X	X
E	4				E	4	X	X		E	4				E	4		
Eb/D#	4				Eb/D#	4				Eb/D#	4				Eb/D#	4		
D	4	X	X		D	4				D	4				D	4	X	X
Db/C#	4				Db/C#	4	X	X		Db/C#	4				Db/C#	4		
C	4				C	4				C	4	X	X		C	4		
B	3				B	3				B	3				B	3		
Bb/A#	3	X	X		Bb/A#	3	X	X		Bb/A#	3				Bb/A#	3	X	X
A	3				A	3				A	3				A	3		
Ab/G#	3				Ab/G#	3				Ab/G#	3				Ab/G#	3		
G	3	X			G	3	X	X		G	3				G	3		
Gb/F#	3				Gb/F#	3				Gb/F#	3				Gb/F#	3		
F	3				F	3				F	3	X	X		F	3		
E	3	X	X		E	3				E	3				E	3		
Eb/D#	3				Eb/D#	3				Eb/D#	3				Eb/D#	3		

D	3				**D**	3				**D**	3				**D**	3		
Db/C#	3				**Db/C#**	3				**Db/C#**	3				**Db/C#**	3		
C	3				**C**	3	**X**	**X**		**C**	3				**C**	3		

Table 3.1 Cont.

B	2				**B**	2				**B**	2				**B**	2		
Bb/A#	2				**Bb/A#**	2				**Bb/A#**	2				**Bb/A#**	2		
A	2				**A**	2				**A**	2				**A**	2		
Ab/G#	2				**Ab/G#**	2				**Ab/G#**	2				**Ab/G#**	2		
G	2				**G**	2				**G**	2				**G**	2		
Gb/F#	2				**Gb/F#**	2				**Gb/F#**	2				**Gb/F#**	2		
F	2				**F**	2				**F**	2				**F**	2		
E	2				**E**	2				**E**	2				**E**	2		
Eb/D#	2				**Eb/D#**	2				**Eb/D#**	2				**Eb/D#**	2		
D	2				**D**	2				**D**	2				**D**	2		
Db/C#	2				**Db/C#**	2				**Db/C#**	2				**Db/C#**	2		
C	2				**C**	2				**C**	2				**C**	2		
Top: 1 **Inner: 2.5** **Bottom: 1** **Total: 4.5** **No. of played notes: 5**					**Top: 1** **Inner: 3** **Bottom: 1** **Total: 5** **No. of played notes: 5**					**Top: 1** **Inner: 3** **Bottom: 1** **Total: 5** **No. of played notes: 5**					**Top: 1** **Inner: 3** **Bottom: 1** **Total: 5** **No. of played notes: 5**			

Table 3.2 Participant data with average and percentage accuracies, and probabilities that scores occurred by chance.

Chord number	Top note	Inner notes	Bottom note	Total score	Index	Average index	No. played notes	Probability score	Weighted score	Average index
5.01	0	3	1	3	80%		4	**0.0004**	0.7997	
5.02	1	3	1	5	100%		5	**0.0000**	1.0000	
5.03	1	2	1	4	80%		4	**0.0004**	0.7997	
5.04	1	3	1	5	100%		5	**0.0000**	1.0000	
5.05	1	3	1	5	100%		5	**0.0000**	1.0000	
5.06	1	2.5	1	4.5	90%		5	**0.0010**	0.8991	
5.07	1	3	1	5	100%		5	**0.0000**	1.0000	
5.08	1	3	1	5	100%		5	**0.0000**	1.0000	
5.09	1	3	1	5	100%		5	**0.0000**	1.0000	
5.10	1	3	1	5	100%		5	**0.0000**	1.0000	
5.11	1	3	1	5	100%		5	**0.0000**	1.0000	
5.12	0	3	1	4	80%		4	**0.0004**	0.7997	
5.13	1	3	1	5	100%		5	**0.0000**	1.0000	
5.14	0	3	1	4	80%		4	**0.0004**	0.7997	
5.15	0	3	1	4	80%		4	**0.0004**	0.7997	
5.16	1	3	1	5	100%		6	**0.0001**	0.9999	
5.17	0	3	0	3	60%		3	**0.0043**	0.5974	
5.18	1	3	1	5	100%		5	**0.0000**	1.0000	
5.19	1	3	1	5	100%		5	**0.0000**	1.0000	
5.20	1	2	1	4	80%	92%	4	**0.0004**	0.7997	0.9147

3.5.8 Explanation of the probabilities and random error

One of the challenging aspects of interpreting the results is that the subjects may have played correct notes accidentally. Clearly, then, the danger for the researcher is that notes played correctly by chance may be misinterpreted as being intentional. It is important to find a way of estimating which notes in a given response were played deliberately or by chance. The aim is to eliminate 'false positives'.

One way of doing this is to work out how many notes in a response would be correct if they really were played by chance. It is not straightforward to discover the degree of imitation (intentionality) in the repetition of pitches; however, a probability model has been constructed (Ockelford, 2012) that enables probabilities to be calculated given any size of chordal stimulus, the response and the pitch universe in which they operate.

To illustrate this, let us assume that we have a bag of five balls, three green and two red. The aim is to pick three green balls. The probability (P) of the first ball that is selected being green is:

$$P(ball\ 1\ correct) = \frac{number\ of\ green\ balls\ in\ the\ bag}{number\ of\ the\ balls\ in\ the\ bag} = \frac{3}{5} = 0.6$$

With notes in chords, the same principle applies. Although the notes in the experiment occur simultaneously, it is theoretically convenient to consider them one by one. So, the probability of getting one note correct given a stimulus formed of three notes within a universe of 5 notes, is 3/5 = 0.6. The probabilities associated with Note 1 can be represented graphically as follows (see Figure 3.4).

3/5=0.6 c (correct)

2/5=0.4 i (incorrect)

Fig. 3.4 Probabilities associated with Note 1 of a 3-note chord in a 5-note universe.

With regard to the second note, the probability of this being correct is contingent on the status of note 1. If note 1 is correct, effectively there are two notes left from the stimulus and 4 in the response domain; in this case the probability of note 2 being correct is:

$$P\left(\frac{note\ 2\ correct}{note\ 1\ correct}\right) = \left(\frac{notes\ in\ the\ stimulus - other\ notes\ correct}{number\ of\ notes\ in\ the\ domain - number\ of\ notes\ in\ the\ response}\right) = \frac{(3-1)}{(5-1)} = \frac{2}{4} = 0.5$$

The probabilities associated with Note 2 can be represented graphically as follows (see Figure 3.5):

2/4=0.5 c (correct) 0.5 *0.6=0.3

3/5=0.6 c (correct)

2/5=0.4 i (incorrect) 0.6*0.5=0.3

3/4=0.75 c (correct) 0.4 *0.75=0.3

2/5=0.4 i (incorrect)

1/4=0.25 i (incorrect) 0.4*0.25=0.1

Fig. 3.5 Probabilities associated with Note 2 of a 3-note chord in a 5-note universe.

This example has been given to show that the scores of the results represent the intentionality of the performance and are not achieved by chance; therefore, a critical part of the analysis is the evaluation of the significance of the results; by weighting the results to correct for random error; in other words to determine how much of the participants' response (raw score) is intentional (the *weighted* score).

In order to compare the results of the disaggregation of different chord sizes, it is then useful to have a formula, which can appropriately calculate the intentionality of the results. Hence the following formula was developed (Ockelford, 2012):

$$Z = R * (1 - P)$$

'Z' represents a single 'weighted' derivation index, based on the product of the proportion of repetition 'R' and the probability that this did not happen by chance (1–P). 'P' here represents the measure of the probability of the results appearing by chance. The results range between 0 and 1.

Selecting a correct note instead of an incorrect one, or conversely picking an incorrect note instead of a correct one, will affect the probability of getting the subsequent notes right or wrong. This phenomenon is called contingent probability, which means the probability that an event will occur is conditional upon previous events. Or, to put it another way, the probability that an event will occur depends on events that have taken place.

Given a universe of 10 notes and a stimulus of one note, by picking one note at random there is a 10% probability of choosing the right one, whereas if a chord has 9 notes there is only a 10% probability that it will *not* be right.

Using two hands, a person can span approximately 25 notes across the keyboard (covering two octaves on the keyboard) at any one time. Hence 25 notes has been chosen as the universe of possibilities. Obviously, this is an approximation, as the number of notes that one can play simultaneously depends on the precise disposition of a particular chord (as some combinations lie more comfortably under the hands than others) and the size and flexibility of the pianist's hands and fingers. Nonetheless, the number that has been chosen as the universe of possibilities provides a fair indication of what is physically possible over a range of conditions.

For example, with a four-note chord, if the subject attempts 1 note, the probability of the note being correct by chance is 4/25. This means that the probability that the note is incorrect is 21/25. If the participant plays the first note correctly, the probability of getting the second note correct is 3/24 and the probability of playing the second note incorrectly is 21/24 (see Figure 3.6). If the first note is incorrect (probability 21/25), then the probability of getting the second note correct is 4/24, and incorrect is 20/24. Hence there is conditional probability in operation; even though the notes are simultaneous, it is easier to treat them sequentially. This complete scenario is shown in Figure 3.6.

The two branches on the left hand side of the page represent the probability pertaining to one note only. The four branches to the right of these relate to *two* notes being played. Probabilities pertaining to two notes are calculated by multiplying the two probabilities presented in the relevant branches. For example, the probability of getting two notes correct is 4/25 x 3/24 = 0.0192. The eight branches on the right of these relate to *three* notes being played. Probabilities pertaining to three notes are calculated by multiplying the three probabilities presented in the relevant branches. The probability of getting three notes correct is 4/25 x 3/24 x 2/23= 0.0167. Following the graph in Figure 3.6 and using the same process that has been described above, the probabilities pertaining to getting different combinations of correct and incorrect notes can be calculated.

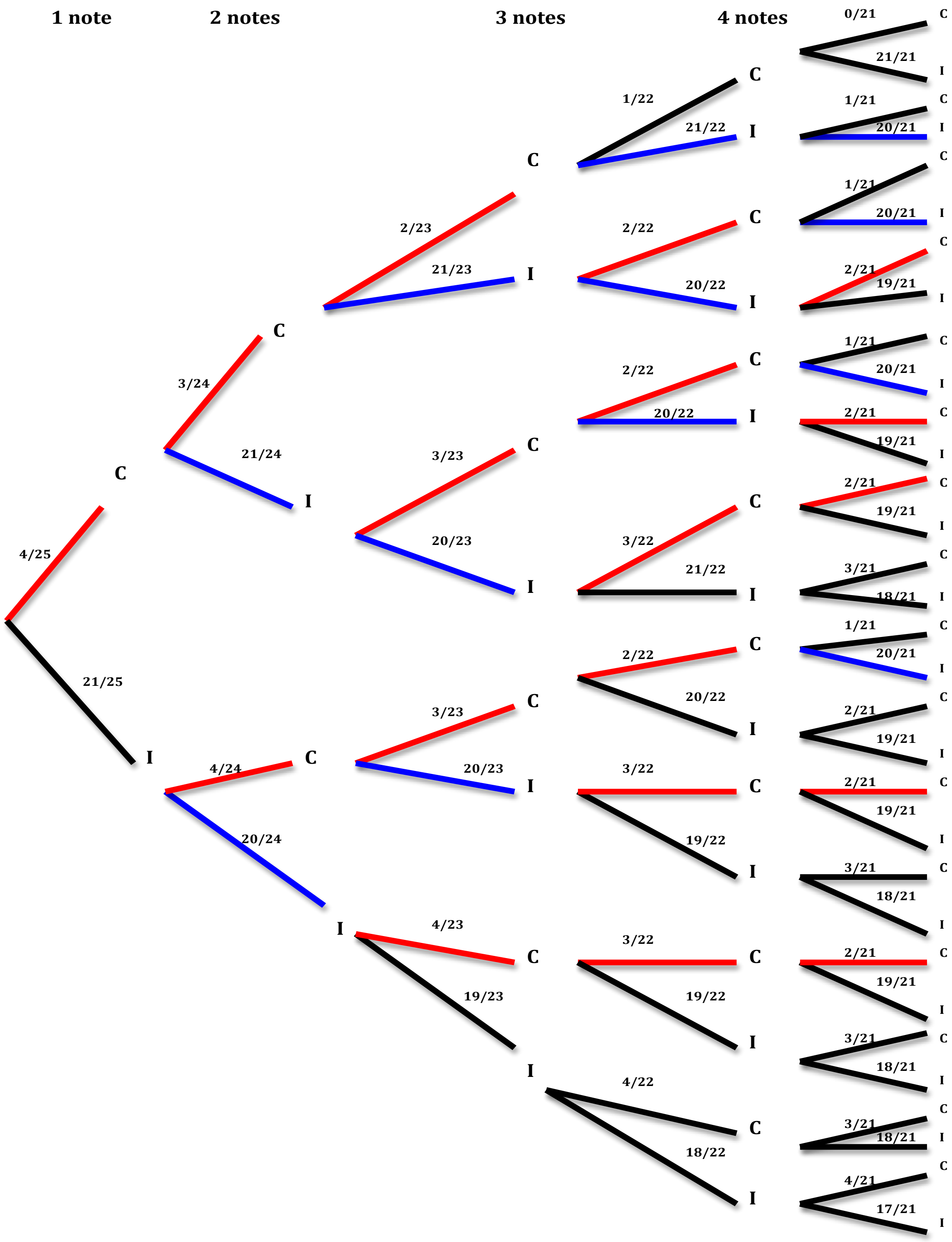


Fig. 3.6 Probability tree showing the probability of getting notes correct or incorrect in a 5-note chord, given a universe of 25 notes.

The probability of getting three notes correct and two incorrect is given by adding together the probabilities pertaining to this combination. Using the numbers shown by the red and blue arrows, the following calculation applies:

4/25*3/24*2/23*21/22*20/21=	((21*20)*(4*3*2))/(25*24*23*22*21)
4/25*3/24*21/23*2/22*20/21=	((21*20)*(4*3*2))/(25*24*23*22*21)
4/25*3/24*21/23*20/22*2/21=	((21*20)*(4*3*2))/(25*24*23*22*21)
4/25*21/24*3/23*2/22*20/21=	((21*20)*(4*3*2))/(25*24*23*22*21)
4/25*21/24*3/23*20/22*2/21=	((21*20)*(4*3*2))/(25*24*23*22*21)
4/25*21/24*20/23*3/22*2/21=	((21*20)*(4*3*2))/(25*24*23*22*21)
21/25*4/24*3/23*2/22*20/21=	((21*20)*(4*3*2))/(25*24*23*22*21)
21/25*4/24*20/23*3/22*2/21=	((21*20)*(4*3*2))/(25*24*23*22*21)
21/25*20/24*4/23*3/22*2/21=	((21*20)*(4*3*2))/(25*24*23*22*21)

P= 9*((21*20)*(4*3*2))/25*24*23*22*21= 0.01423

Following the lines that include the combination of correct and incorrect notes, and multiplying these numbers gives the probability that participants played these notes by chance. Therefore, the probability of playing by chance five notes with three correct and two incorrect in a universe of 25 is 0.01423.

A weighted score can then be obtained using the Z = R*(1–**P**) formula by multiplying the number of correct notes played in a particular chord by the difference between 1 and P.

This principle is extended to all other possible combinations of stimuli, responses and notes correct (given a universe of 25 pitches), and, using Excel spreadsheets, the results given in Tables 3.3 to 3.8 are obtained (see Appendix II).

Given that it is possible to achieve a score of 0.5 (for a correct pitch played in the wrong octave), probability figures are extrapolated from whole number values. For example, the probability of getting 2.5 notes correct when playing 3 notes in response to a stimulus of 4 notes is 0.0283 (see Table 3.3); this represents an approximation, but an acceptable one. Observe also that the size of the response may well be larger than the stimulus (see Table 3.7); again, probability figures are extrapolated from whole number values, for example the probability of getting 3.5 notes correct when playing 11 notes in response to an 8-note stimulus (meaning that the participant played two notes with one finger) is 0.3059.

Table 3.3 Probability scores for 4 note chords.

4 note chords							
Number of notes correct	**Number of notes attempted**						
	0	**1**	**2**	**3**	**4**	**5**	**6**
0	1.0000	0.8400	0.6997	0.5782	0.4731	0.3830	0.3064
0.5				0.4717	0.4468		
1		0.1600	0.2803	0.3652	0.4206	0.4506	0.4596
1.5			0.1501	0.2100	0.2601	0.3004	0.3305
2			0.0200	0.0548	0.0996	0.1502	0.2015
2.5				0.0283	0.0531	0.0830	
3				0.0017	0.0066	0.0158	0.0300
3.5					0.0034	0.0081	
4					0.0001	0.0004	0.0143
Sum	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 3.4 Probability scores for 5 note chords.

5 note chords								
Number of notes correct	**Number of notes attempted**							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	1.0000	0.8000	0.6333	0.4957	0.3830	0.2918	0.2335	0.1720
0.5			0.4833		0.4168	0.3739	0.3351	
1		0.2000	0.3333	0.4130	0.4506	0.4560	0.4368	0.4063
1.5			0.1833	0.2500	0.3004	0.3353		
2			0.0333	0.0870	0.1502	0.2146	0.2577	0.3090
2.5				0.0457	0.0830	0.1252	0.1603	
3				0.0043	0.0158	0.0358	0.0628	0.0997
3.5					0.0081	0.0188	0.0359	
4					0.0004	0.0019	0.0091	0.0125
4.5						0.0010	0.0046	
5						0.0000	0.0001	0.0004
Sum	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 3.5 Probability scores for 6 note chords.

6 note chords								
Number of notes correct	**Number of notes attempted**							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	1.0000	0.7600	0.5700	0.4213	0.3064	0.2189	0.1641	0.1123
0.5				0.4337	0.3830	0.3283	0.2801	0.2280
1		0.2400	0.3800	0.4461	0.4596	0.4377	0.3961	0.3437
1.5					0.3312	0.3556	0.3543	0.3473
2			0.0500	0.1239	0.2028	0.2736	0.3124	0.3509
2.5				0.0663	0.1164	0.1690	0.2091	0.2552
3				0.0087	0.0300	0.0644	0.1057	0.1594
3.5					0.0156	0.0349	0.0633	0.0954
4					0.0012	0.0054	0.0209	0.0314
4.5						0.0027	0.0108	0.0168
5						0.0001	0.0006	0.0022
5.5							0.0003	0.0011
6							0.0000	0.0000
Sum	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 3.6 Probability scores for 7 note chords.

7 note chords											
Number of notes correct	**Number of notes attempted**										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	1.0000	0.7200	0.5100	0.3548	0.2419	0.1613	0.1129	0.0713			
0.5				0.4102	0.3467						
1		0.2800	0.4200	0.4657	0.4515	0.4032	0.3427	0.2761			
1.5				0.3150	0.3528	0.3628	0.3451	0.3236			
2			0.0700	0.1643	0.2540	0.3225	0.3475	0.3711			
2.5				0.0898	0.1519	0.2117	0.2512				
3				0.0152	0.0498	0.1008	0.1549	0.2159			0.3408
3.5					0.0263	0.0563	0.0974	0.1353			0.2698
4					0.0028	0.0119	0.0398	0.0547			0.1988
4.5						0.0061	0.0210	0.0299			
5						0.0004	0.0022	0.0051	0.0158		
5.5								0.0025			
6							0.0000	0.0000	0.0010		
6.5								0.0000			
7								0.0000			0.0002
Sum	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0			

Table 3.7 Probability scores for 8 note chords.

8 note chords												
Number of notes correct	**Number of notes attempted**											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
0	1.0000	0.6800	0.4533	0.2957	0.1881	0.1165	0.0699	0.0405	0.0225			
0.5			0.4533	0.3843								
1		0.3200	0.4533	0.4730	0.4300	0.3584	0.2795	0.2060	0.1438			
1.5					0.3655	0.3584			0.2321			
2			0.0933	0.2070	0.3010	0.3584	0.3763	0.3604	0.3204		0.2082	
2.5					0.1881	0.2509	0.2957	0.3189	0.3204		0.2707	
3				0.0243	0.0753	0.1433	0.2150	0.2773	0.3204		0.3332	0.3054
3.5					0.0404	0.0829	0.1344		0.2372			0.3059
4					0.0055	0.0224	0.0538	0.0990	0.1540	0.2120	0.2650	0.3063
4.5						0.0117	0.0296	0.0574	0.0946		0.1855	
5						0.0011	0.0054	0.0158	0.0352		0.1060	
5.5							0.0028	0.0084			0.0632	
6							0.0002	0.0010	0.0035	0.0093	0.0204	
6.5								0.0005				
7								0.0000	0.0001		0.0017	
7.5									0.0001			
8									0.0000		0.0000	
Sum	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0			

Table 3.8 Probability scores for 9 note chords.

9 note chords												
Number of notes correct	**Number of notes attempted**											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
0	1.0000	0.6400	0.4000	0.2435	0.1439	0.0822	0.0452	0.0238	0.0119	0.0056		
0.5									0.0535			
1		0.3600	0.4800	0.4696	0.3984	0.3083	0.2220	0.1499	0.0952	0.0567		
1.5					0.3700	0.3439	0.2960	0.2385	0.1809			
2			0.1200	0.2504	0.3415	0.3794	0.3700	0.3271	0.2665	0.2016		
2.5					0.2239	0.2846	0.3178		0.3029	0.2654		
3				0.0365	0.1062	0.1897	0.2656	0.3180	0.3392	0.3293	0.2940	
3.5					0.0581	0.1138	0.1755	0.2324	0.2756			
4					0.0100	0.0379	0.0854	0.1468	0.2120	0.2694	0.3102	
4.5						0.0202	0.0484	0.0891	0.1386	0.1908	0.2399	
5						0.0024	0.0114	0.0315	0.0652	0.1122	0.1697	0.2264
5.5							0.0059	0.0171		0.0676	0.1082	
6							0.0005	0.0028	0.0093	0.0230	0.0468	0.0828
6.5								0.0014	0.0049			
7								0.0001	0.0005	0.0021	0.0062	
7.5									0.0003	0.0011		
8									0.0000	0.0001	0.0003	
8.5											0.0002	
9										0.0000	0.0000	
Sum	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		

3.6 Results

3.6.1 Introduction

To further understand more fully the participants' perceptual processing, the results can be analysed in relation to different parameters. The paragraphs below explain the results, taking into consideration the following variables:

1. Chord size;
2. Chord complexity (four categories: simple diatonic, higher diatonic, chromatic and note cluster);
3. With tonal implication and without tonal implication;
4. Position of notes in chord (top, 'inner', bottom);
5. Analysis of individual cases: NS, AH and CP.

3.6.2 Savant and comparison participants: weighted and non-weighted data

The graphs below show the mean weighted and non-weighted scores of a savant participant (NS) from the chord experiment test, in which he had to listen to increasingly complex chords and imitate them (see Figure 3.7 and Table 3.9).

The numbers on the *x-axis* show the mean score that NS obtained in relation to the chords of different sizes, which are represented on the *y-axis*. The *y-axis* represents the size of the groups of chords – 4 means the chords formed by 4 notes, etc. – in terms of their constituent elements (each chord group had 20 examples, the overall assessment was of 6 groups, providing a total of 120 examples).

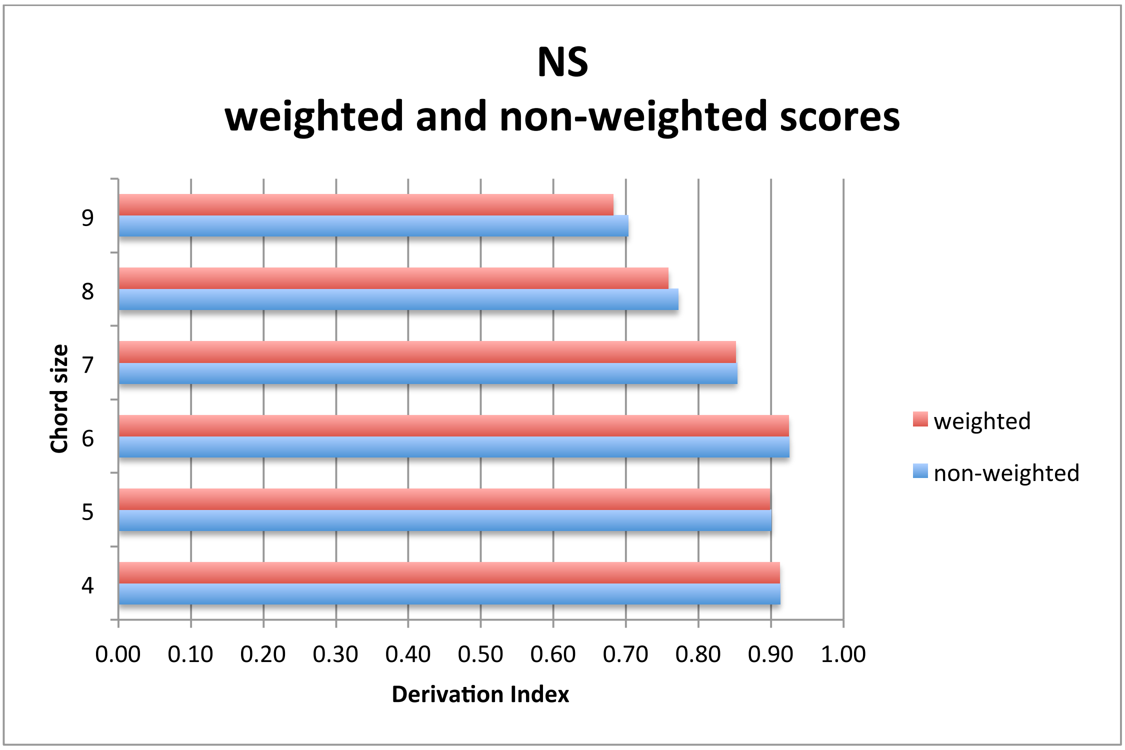


Fig. 3.7 NS's weighted and non-weighted scores.

Table 3.9 NS's weighted and non-weighted scores.

Size of the chord	NS non-weighted score	NS weighted score
4	0.9125	0.9118
5	0.9000	0.8983
6	0.9250	0.9242
7	0.8536	0.8511
8	0.7719	0.7582
9	0.7028	0.6824

As Figure 3.7 and Table 3.9 display, the non-weighted and weighted scores are almost identical; then it is possible to assume that NS's responses are almost entirely imitative. Hence, in the case of NS the probability of achieving the score by chance is negligible and we can infer that the notes played are almost entirely intentional. Below is another example of the weighted and non-weighted scores of a non-savant comparison subject, AH (see Figure 3.8 and Table 3.10).

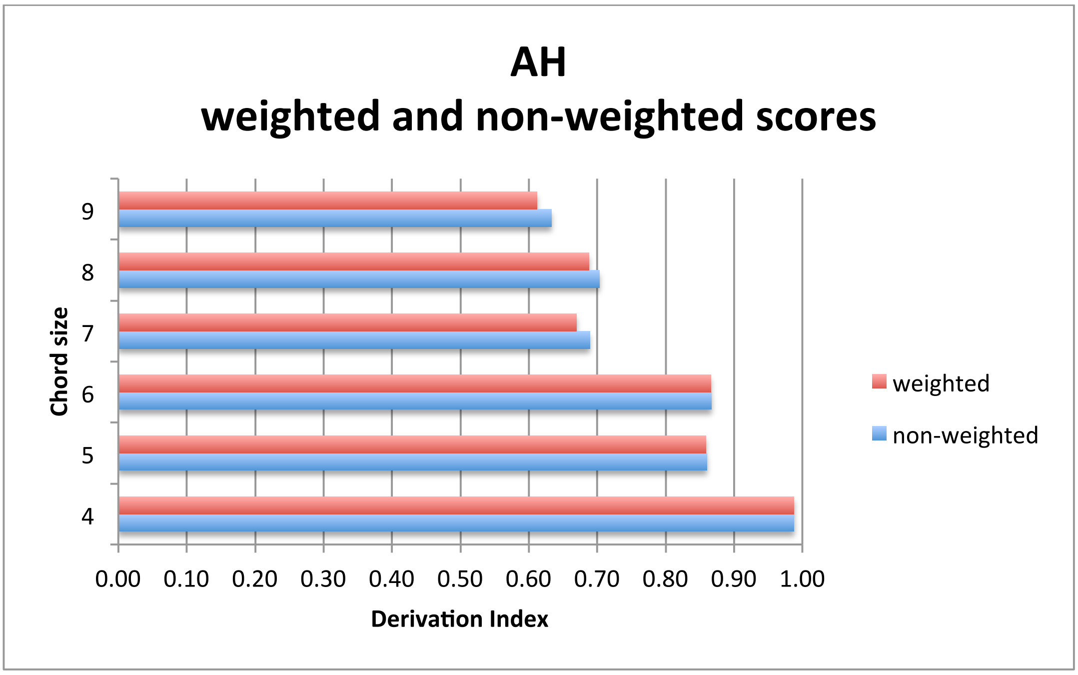


Fig. 3.8 AH's weighted and non-weighted scores.

Table 3.10 AH's weighted and non-weighted scores.

Size of the chord	AH non-weighted score	AH weighted score
4	0.9875	0.9874
5	0.8600	0.8588
6	0.8667	0.8661
7	0.6893	0.6698
8	0.7031	0.6880
9	0.6333	0.6117

As Table 3.10 and Figure 3.8 show, the non-weighted and weighted scores are almost identical. As for NS (see Figure 3.7), it can be inferred that AH's responses are almost entirely imitative. Hence, the probability of AH achieving these scores by chance is negligible, and it can be assumed that the notes played are primarily intentional.

Below is another example of the non-weighted and weighted scores of a comparison subject, CP (Figure 3.9 and Table 3.11).

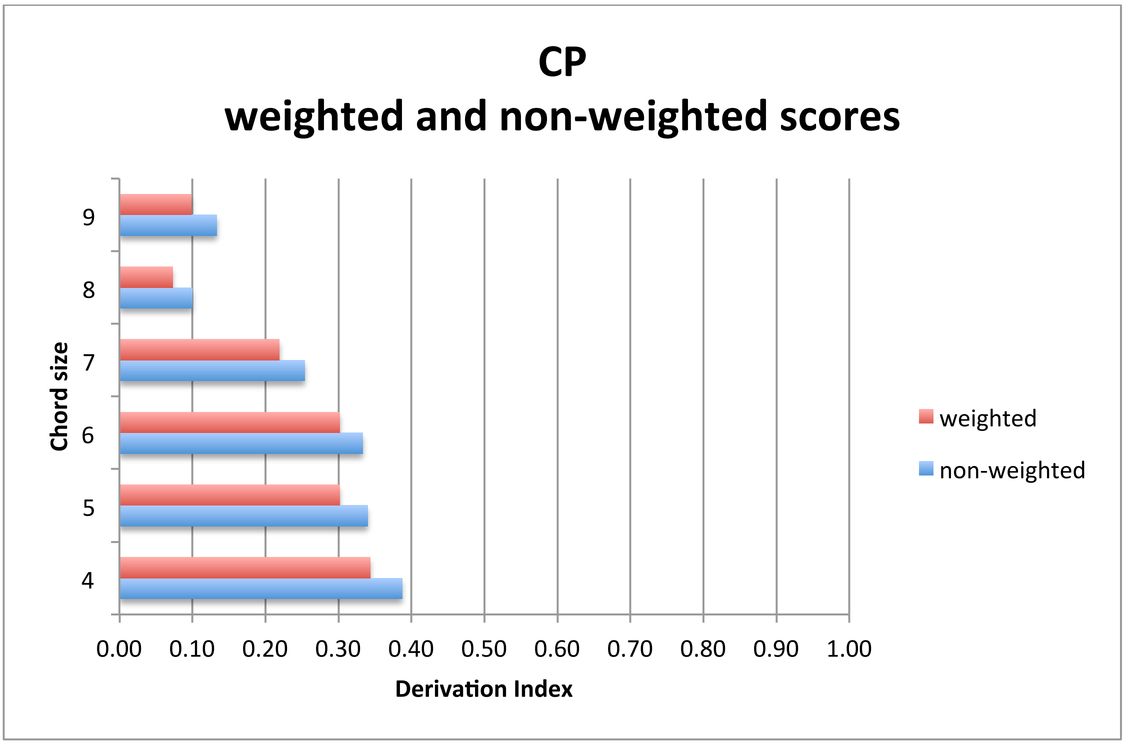


Fig. 3.9 CP's weighted and non-weighted scores.

Table 3.11 CP's weighted and non-weighted scores.

Size of the chord	CP non-weighted score	CP weighted score
4	0.3875	0.3436
5	0.3400	0.3016
6	0.3333	0.3018
7	0.2536	0.2192
8	0.1000	0.0729
9	0.1333	0.0986

As Table 3.11 and Figure 3.9 show, the difference between CP's two scores are greater than the differences for NS and AH; therefore, it is likely that some of CP's results are achieved by chance. Overall, the savant participants show smaller differences between their raw and weighted scores than the comparison group (see Table 3.12), although some members of the latter group (such as AH, ZV and SX; see Table 3.13) also show only minor differences between raw and weighted scores. It can be inferred, therefore, that participants who find the task easier do not tend to play by chance. Conversely, those who find the task difficult and achieve less accuracy are more inclined to play by chance (see Table 3.13).

Table 3.12 Savants' raw and weighted scores. The raw data are represented as a percentage and weighted scores in numbers.

Savant participants' raw data						
	DP	**AJ**	**VX**	**LH**	**NS**	**GN**
4	100.00%	98.75%	94.38%	92.50%	91.25%	85.63%
5	95.50%	95.50%	91.50%	90.00%	90.00%	78.00%
6	97.50%	95.83%	86.67%	81.67%	92.50%	72.92%
7	94.06%	91.07%	82.14%	70.36%	85.36%	68.93%
8	92.78%	81.56%	69.69%	59.06%	77.19%	61.88%
9	92.78%	77.22%	66.39%	53.06%	70.28%	55.00%
Savant participants' weighted data						
	DP	**AJ**	**VX**	**LH**	**NS**	**GN**
4	0.9991	0.9873	0.9418	0.9205	0.9118	0.8460
5	0.9546	0.9546	0.9147	0.8975	0.8983	0.7681
6	0.9749	0.9583	0.8664	0.8116	0.9242	0.7118
7	0.9641	0.9102	0.8210	0.7024	0.8511	0.6699
8	0.9405	0.8128	0.6881	0.5544	0.7582	0.5835
9	0.9255	0.7712	0.6481	0.4948	0.6824	0.5202

Table 3.13 Comparison participants' raw and weighted scores.

Comparison participants' raw data								
	AH	**ZV**	**SX**	**DO**	**HB**	**CG**	**AM**	**AN**
4	98.75%	95.00%	86.88%	68.75%	66.88%	60.00%	59.38%	73.13%
5	86.00%	82.50%	80.50%	52.00%	55.00%	63.00%	54.00%	67.50%
6	86.67%	80.83%	77.50%	32.92%	56.25%	63.75%	46.25%	59.58%
7	68.93%	70.36%	67.14%	36.79%	60.00%	57.14%	45.36%	58.21%
8	70.31%	62.50%	56.56%	36.25%	51.56%	50.94%	44.06%	50.31%
9	63.33%	56.67%	57.22%	30.00%	51.11%	56.11%	38.89%	46.11%
Comparison participants' weighted data								
	AH	**ZV**	**SX**	**DO**	**HB**	**CG**	**AM**	**AN**
4	0.9874	0.9497	0.8611	0.6632	0.6500	0.5921	0.5644	0.5644
5	0.8588	0.8236	0.7932	0.4770	0.5193	0.5971	0.5087	0.5087
6	0.8661	0.8055	0.7641	0.2730	0.5410	0.6128	0.4237	0.4237
7	0.6698	0.6944	0.6490	0.3275	0.5785	0.5401	0.4228	0.4257
8	0.6880	0.6131	0.5239	0.3275	0.4678	0.4742	0.3771	0.3833
9	0.6117	0.5489	0.5271	0.2608	0.4675	0.5206	0.3389	0.3389

Table 3.13 Cont.

Comparison participants' raw data									
	UN	**ZU**	**JC**	**JT**	**CP**	**VG**	**LP**	**RK**	**JP**
4	58.75%	54.38%	45.63%	47.50%	38.75%	37.50%	38.75%	27.50%	12.50%
5	44.00%	51.50%	42.50%	41.50%	34.00%	57.50%	34.00%	34.50%	23.50%
6	45.00%	45.83%	37.08%	47.08%	33.33%	47.92%	43.75%	35.83%	17.92%
7	42.14%	46.43%	31.07%	43.57%	25.36%	42.14%	38.57%	46.07%	26.43%
8	47.50%	41.25%	35.94%	37.19%	10.00%	38.44%	36.25%	44.69%	24.06%
9	42.78%	34.44%	31.39%	38.33%	13.33%	30.83%	40.83%	38.89%	26.39%
Comparison participants' weighted data									
	UN	**ZU**	**JC**	**JT**	**CP**	**VG**	**LP**	**RK**	**JP**
4	0.5468	0.5097	0.4122	0.4420	0.3436	0.3331	0.3218	0.2463	0.1021
5	0.3946	0.4837	0.3748	0.3720	0.3016	0.5367	0.2624	0.2944	0.1845
6	0.4077	0.4170	0.3143	0.4423	0.3018	0.4468	0.3707	0.3172	0.1221
7	0.3590	0.4319	0.2555	0.4026	0.2192	0.3829	0.3344	0.4227	0.2037
8	0.4154	0.3604	0.2975	0.3365	0.0729	0.3394	0.2861	0.3802	0.1842
9	0.3773	0.2919	0.2613	0.3516	0.0986	0.2561	0.3506	0.3250	0.1970

3.6.3 Analysis of performances by chord size

In the following graphs, the *x-axis* gives the size of the groups of chords, which ranged from 4 to 9 notes. Each chord group has 20 examples; thus the overall assessment is of 6 groups x 20 examples each = 120 examples in total. The *y-axis* shows the mean percentage of correct chords that are obtained from the analyses of the individual performances of the n=6 savants and n=17 non-savants in the comparison group. Figure 3.10 displays the composite data for all participants, Figure 3.11 the savant group and Figure 3.12 the non-savant comparison scores.

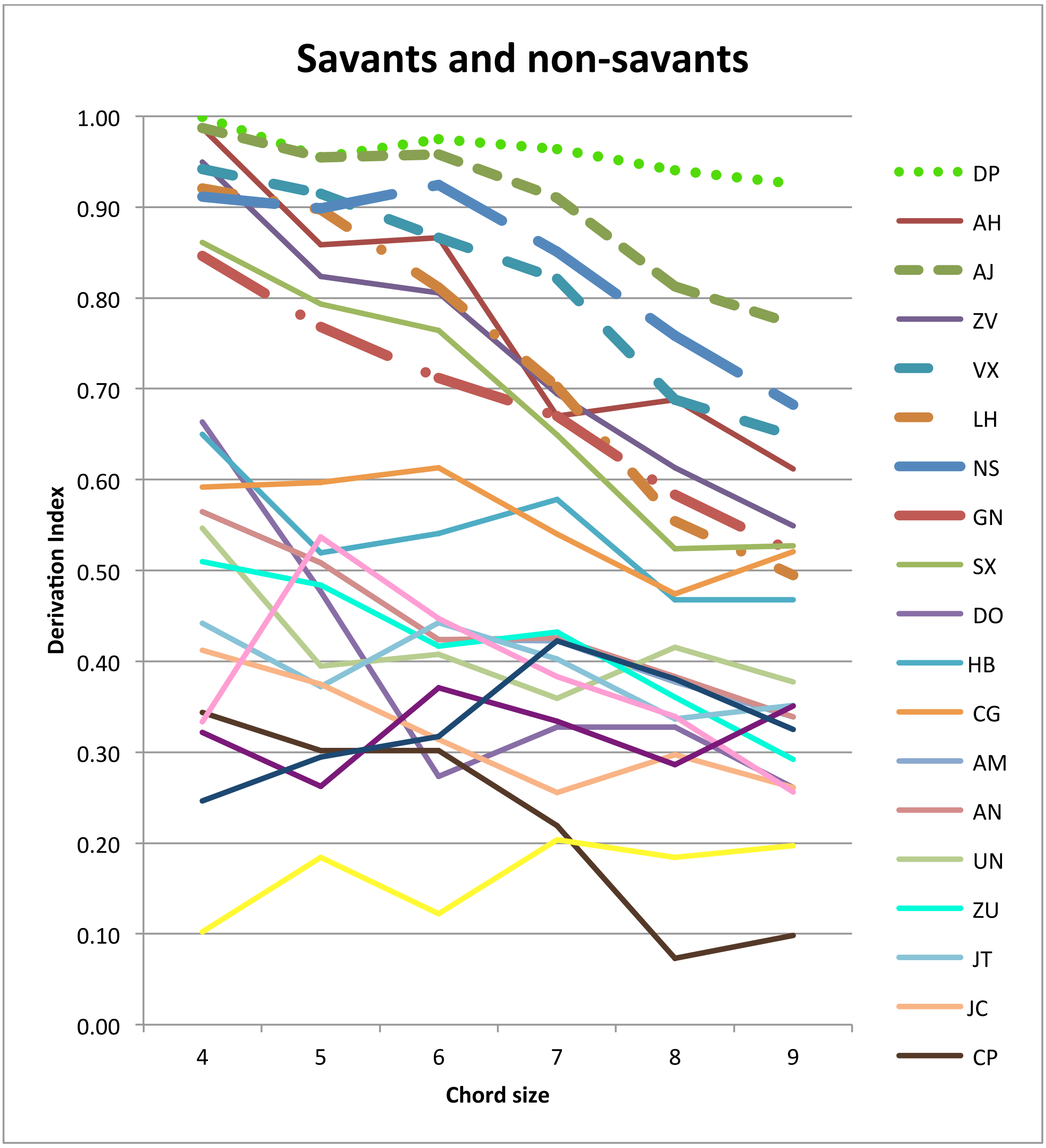


Fig. 3.10 Scores for the two groups (savants and non-savants) for each set of 20 chords.

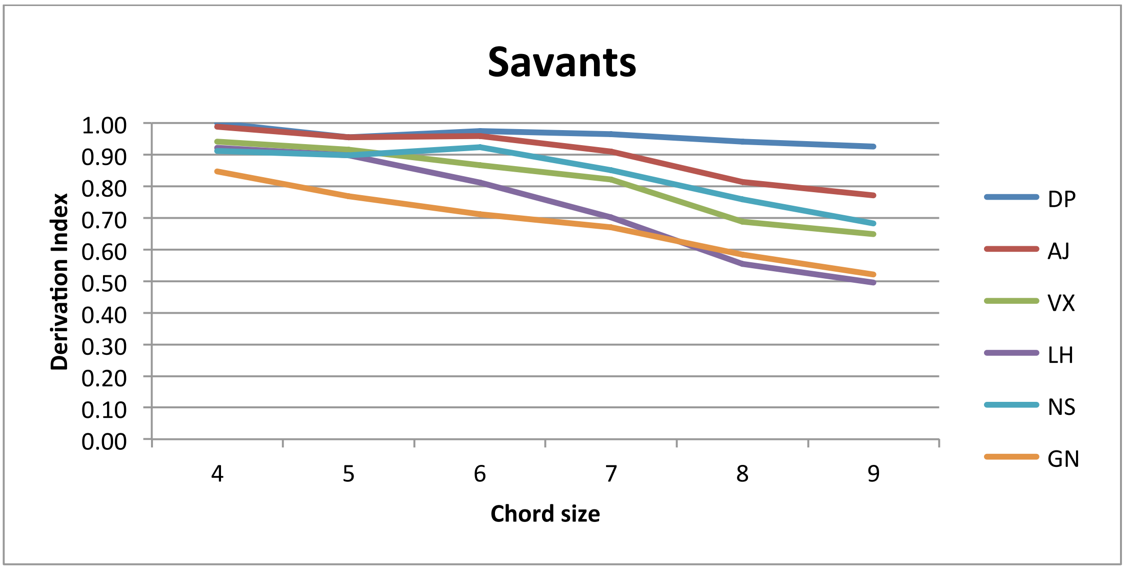


Fig. 3.11 Scores for savants for each set of 20 chords.

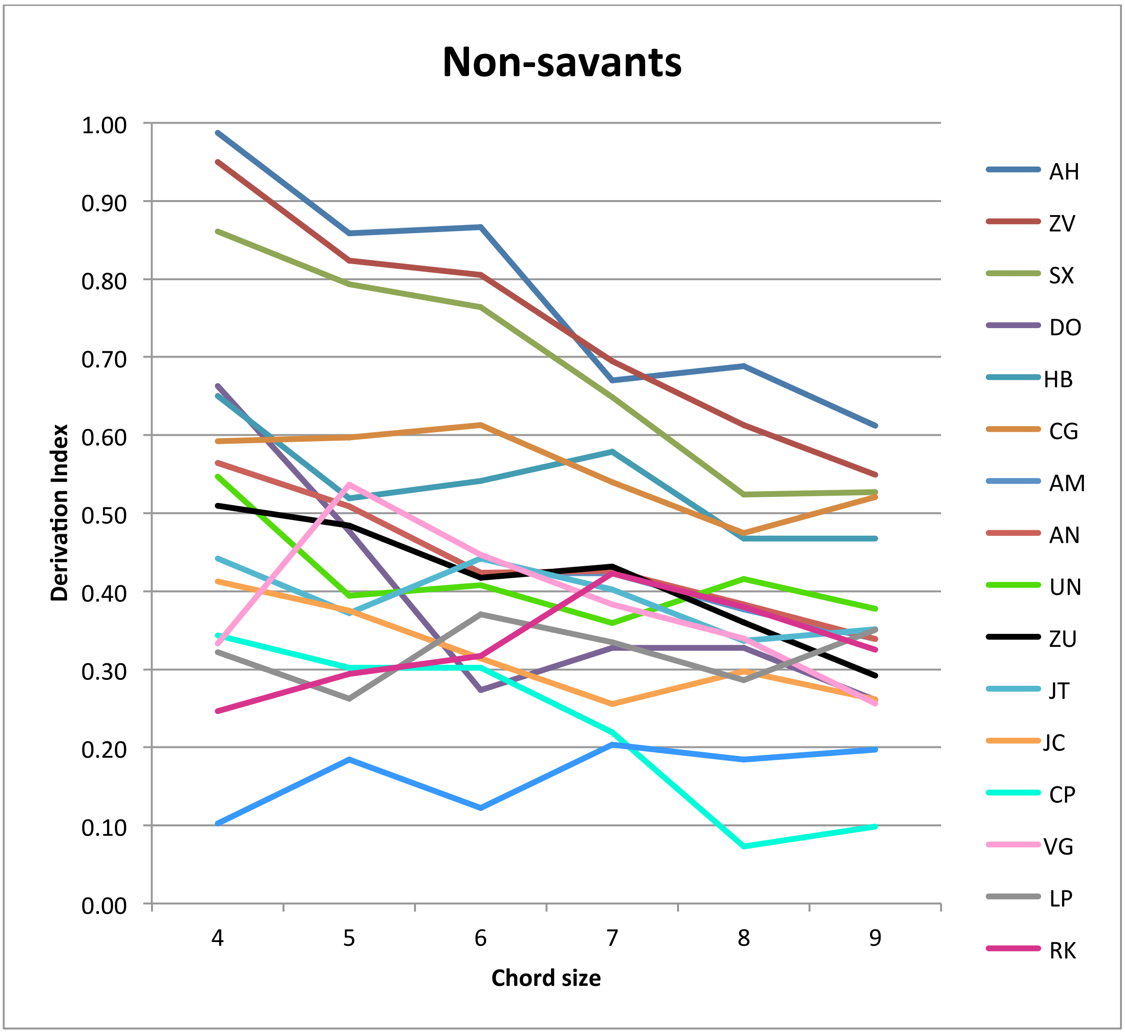


Fig. 3.12 Scores for the non-savant participants, for each set of 20 chords.

The above graphs illustrate how the average scores across all participants decrease as the size of the chords increase; this shows that the task becomes more difficult the more notes there are within the chords. As well as perceptual limitations, this could suggest that the task also becomes more difficult physically. Figures 3.13 and 3.14, and Table 3.14 highlight a difference between the savants' and non-savants' mean percentage accuracy.

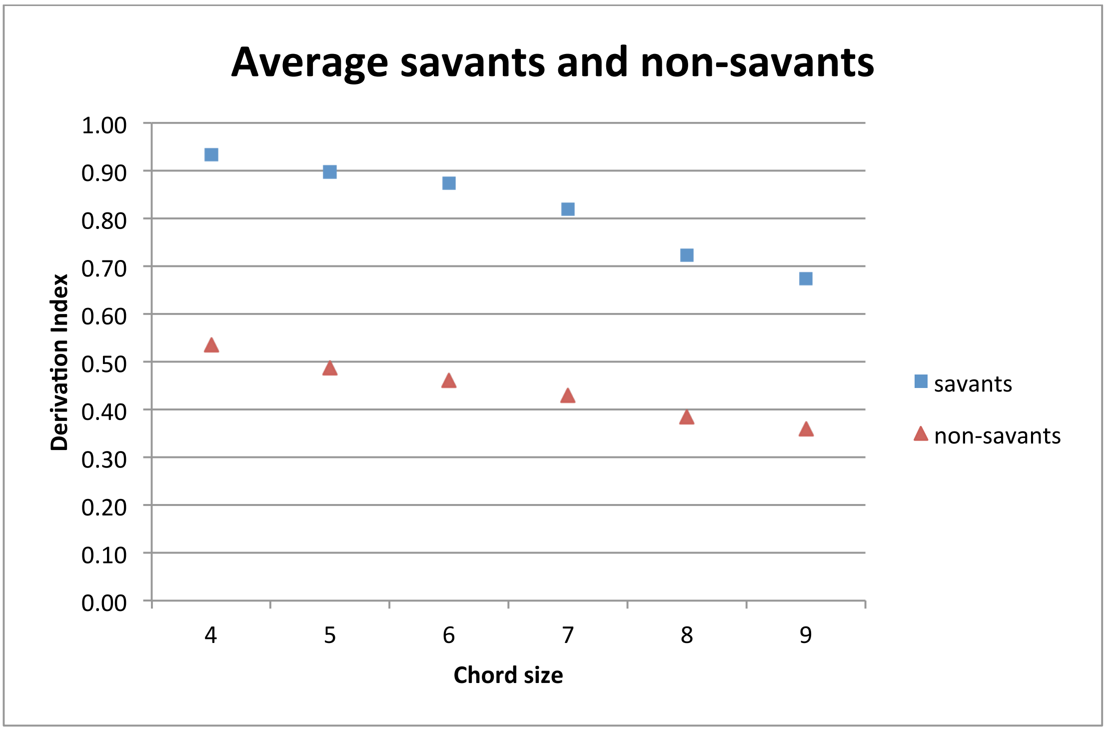


Fig. 3.13 Average scores of the savants and non-savant groups for the chord experiment.

Table 3.14 Means and standard deviations of savants and non-savants comparison for the chord experiment.

Size of the chord	Savants	SD	Non-savant Comparisons	SD
4	0.9344	0.1069	0.5347	0.2209
5	0.8980	0.1189	0.4877	0.2036
6	0.8745	0.1205	0.4618	0.2005
7	0.8198	0.1327	0.4306	0.2077
8	0.7229	0.1613	0.3840	0.1738
9	0.6737	0.1745	0.3602	0.1823

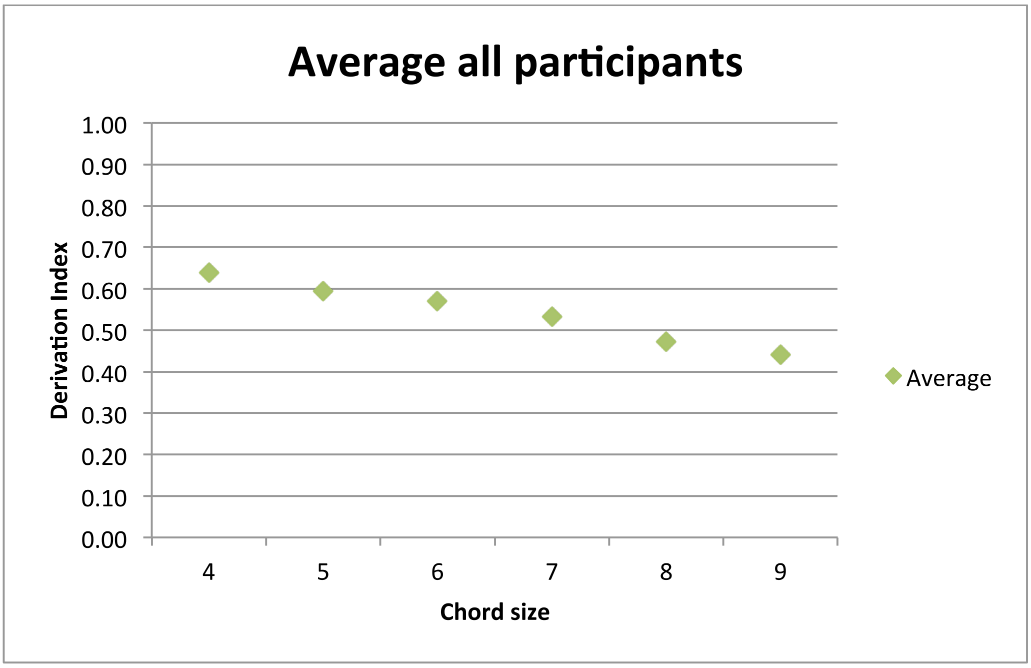


Fig. 3.14 The average score of all the participants.

In summary:

- On average, the savants perform better than the non-savants across all chord sizes, although there is some overlap (Figure 3.10); in comparing the mean scores, there are similarities between the savant who achieves the least accuracy and comparison subject who reaches the best score (Figure 3.13);

- A minority of the comparison group is similar to the savants, however the majority of the non-savant comparison participants perform less successfully (Figure 3.10).

The graph below shows how individual's performances vary in relation to chord size. The *x-axis* displays all the participants. The *y-axis* shows the scores obtained for each chord size. The graph illustrates that the savant group's scores are more consistent across different chord sizes, compared to the comparison group. However, a minority of the comparison subjects behave similarly to the savant group, such as AH and ZV (see Figure 3.15).

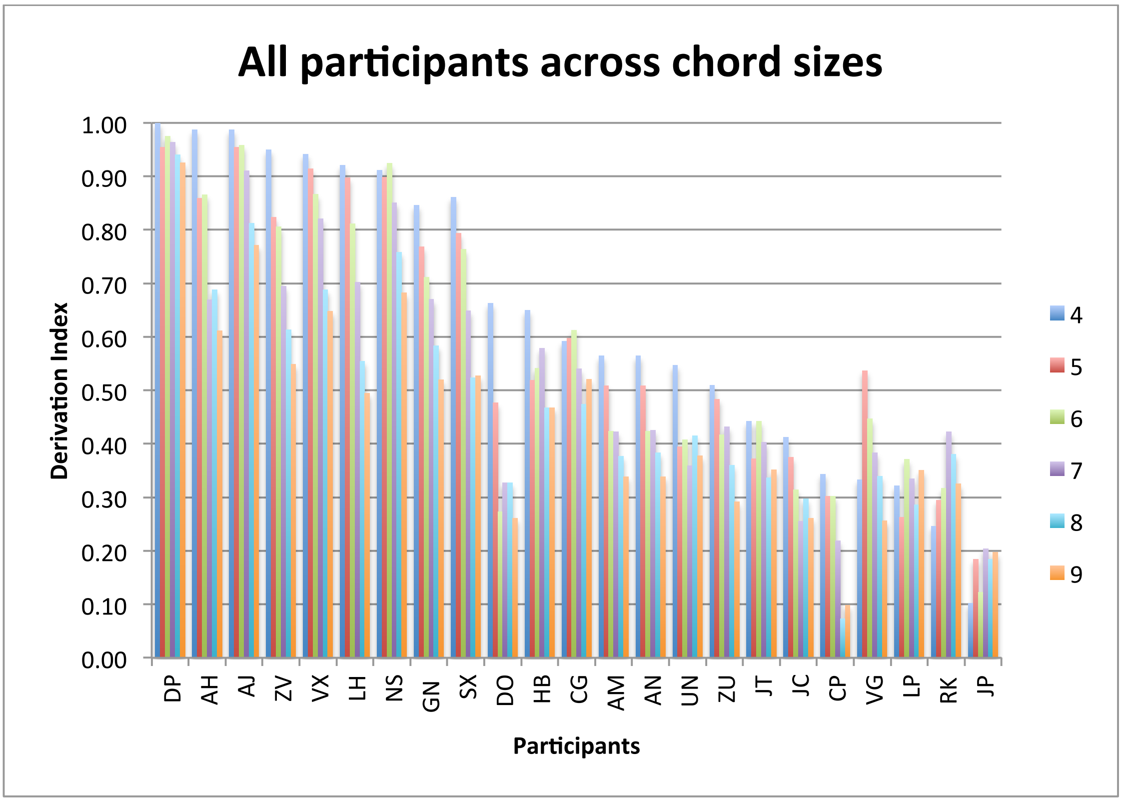


Fig. 3.15 Performances of all the participants across the chord sizes.

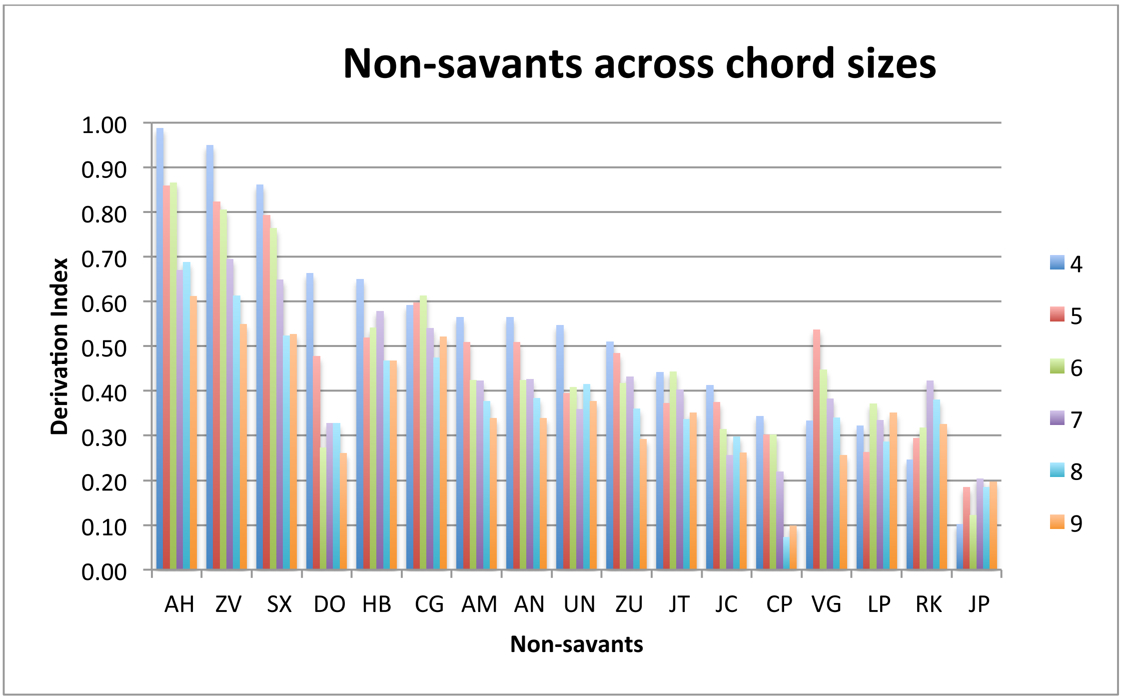


Fig. 3.16 Performances of non-savant participants across all chord sizes.

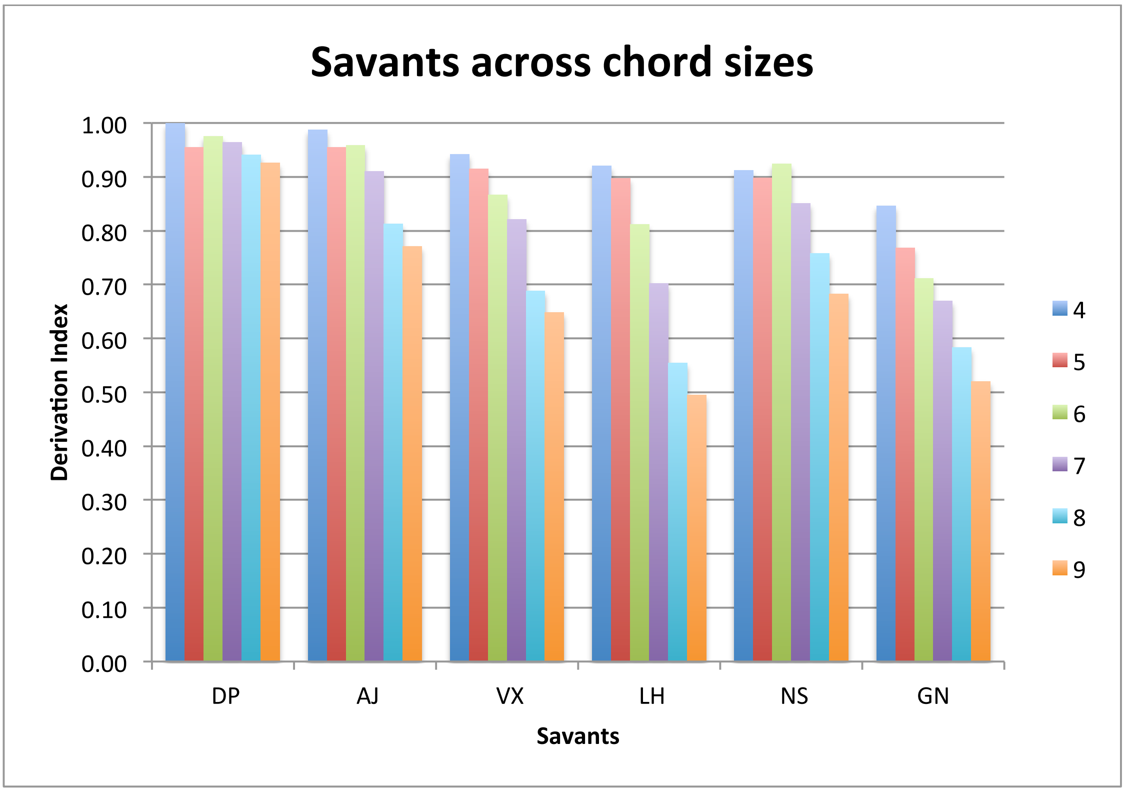


Fig. 3.17 Performances of the savant sample across the chord sizes.

In summary:

- As the graphs above show, all participants demonstrate greater variation in scores as the number of notes in the stimuli increase; in other words both savants and non-savants display greater variation in their performances as the task becomes more complex;

- In the savant group the fewest errors are to be found in DP's scores and the most in LH's scores (see Figure 3.17). Also, the non-savant group (see Figure 3.16) shows lower variation in scores between different groups of chords (e.g. JT and LP), however with a much lower level of accuracy overall;

- The highest score achieved for a group of chords by a savant (DP) is 1.0 accuracy and the highest score obtained by a non-savant (AH) is 0.99; the lowest savant score is 0.49, and 0.07 is obtained by a non-savant (CP).

AH's outstanding results lead us to hypothesise that she applies an effective strategy, thus suggesting that some of the non-savants and the savants use similar strategies.

3.6.4 Analysis of performances by chordal complexity

The stimuli may be divided into five groups based on their level of complexity, using criteria based on harmonic rules (Piston, 1946). As the perception of consonant harmony is more straightforward than a dissonant one, consonant chords are categorised as having a lower degree of difficulty, (levels 1 and 2; see Figures 3.18 and 3.19).

Conversely, chords with a more complex harmonic structure, which are more dissonant and therefore more difficult to process, are placed in a higher difficulty category (levels 3, 4 and 5; see Figures 3.20, 3.21 and 3.22).

To classify the level of complexity of the chords, the following scoring system has been devised:

Triadic chords (containing only roots, 3^{rds} and 5^{ths}):	Level 1
7th and 9th chords:	Level 2
11th and 13th chords:	Level 3
Whole tone cluster	Level 3
11th and 13th + chromatic alteration	Level 4
Semitonal cluster	Level 4
Mixed cluster	Level 5

Subsequently, groups four and five were merged as there were no statistical differences (in participants' scores) between them, thus creating four levels only (see Figure 3.23).

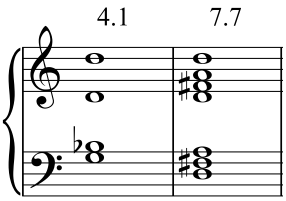


Fig. 3.18 Chord complexity Level 1.

Fig. 3.19 Chord complexity Level 2.

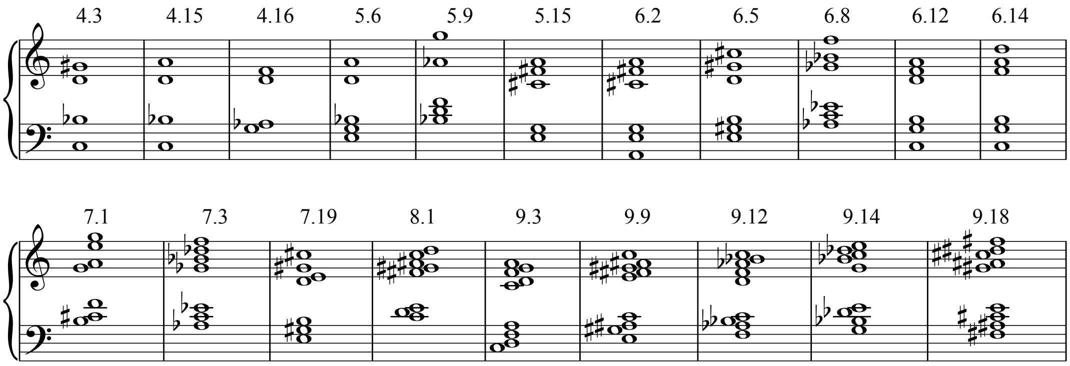


Fig. 3.20 Chord complexity Level 3.

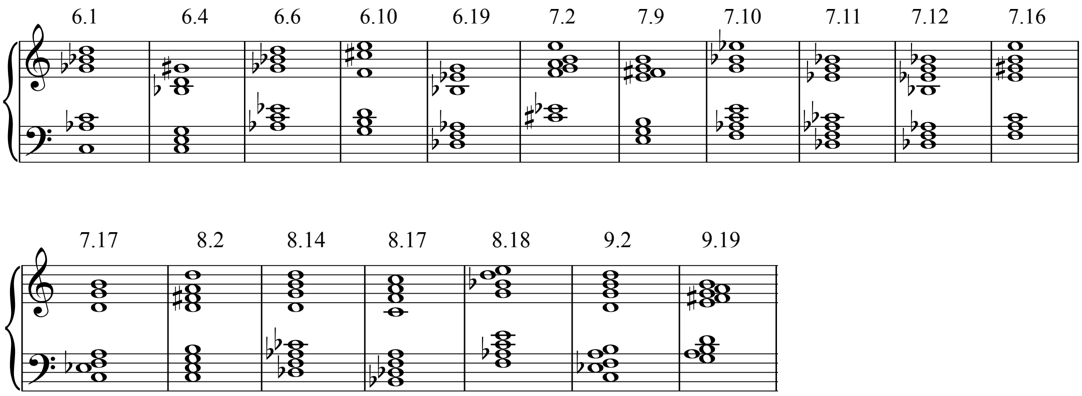


Fig 3.21 Chord complexity Level 4.

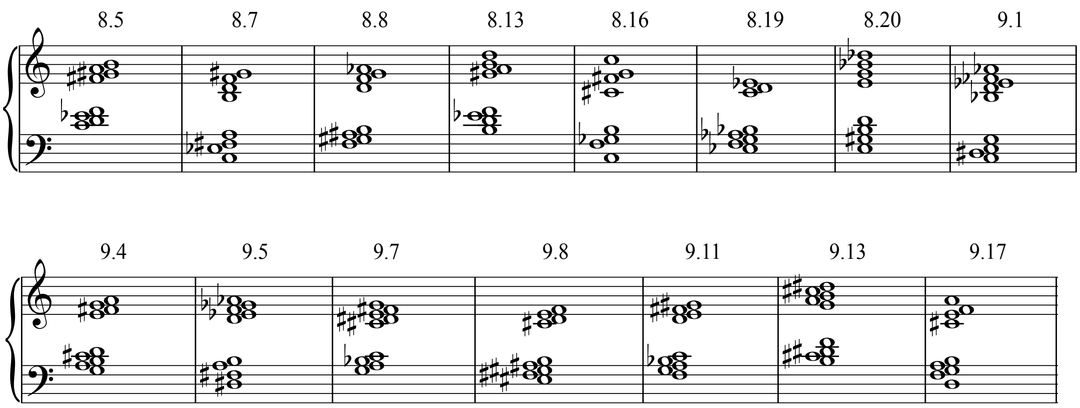


Fig. 3.22 Chord complexity Level 5.

Fig. 3.23 Chordal complexity 'new level 4' (level 4 and 5 were merged to form this new level).

In Figure 3.32, the *x-axis* represents all the participants and the *y-axis* displays the various levels of chordal complexity from 1 to 4. Figure 3.24 shows that both savants' and non-savants' performances decrease in accuracy when the task becomes more complex; however, the savant group exhibits more accuracy across all levels of chordal complexity than the non-savant comparison group, with the exception of LH and GN (Figures 3.24, 3.25 and 3.26).

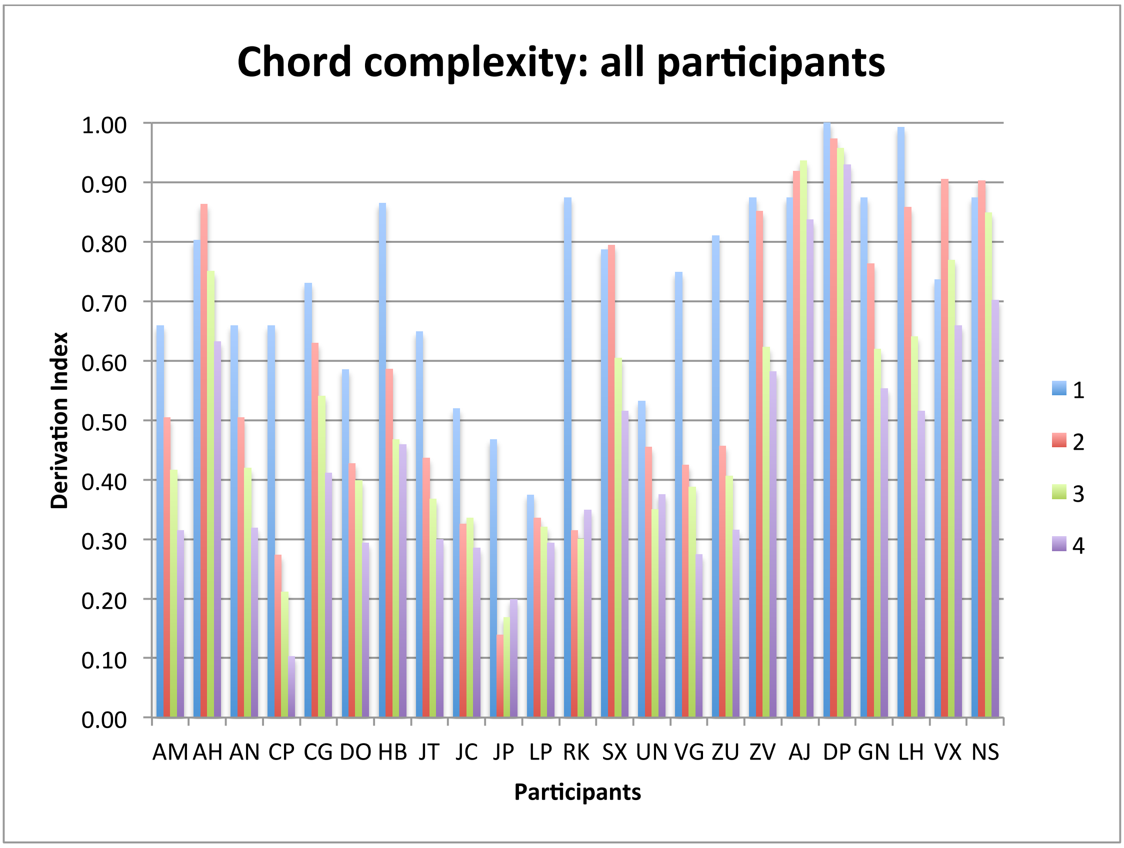


Fig. 3.24 Scores for all participants for the different complexity levels.

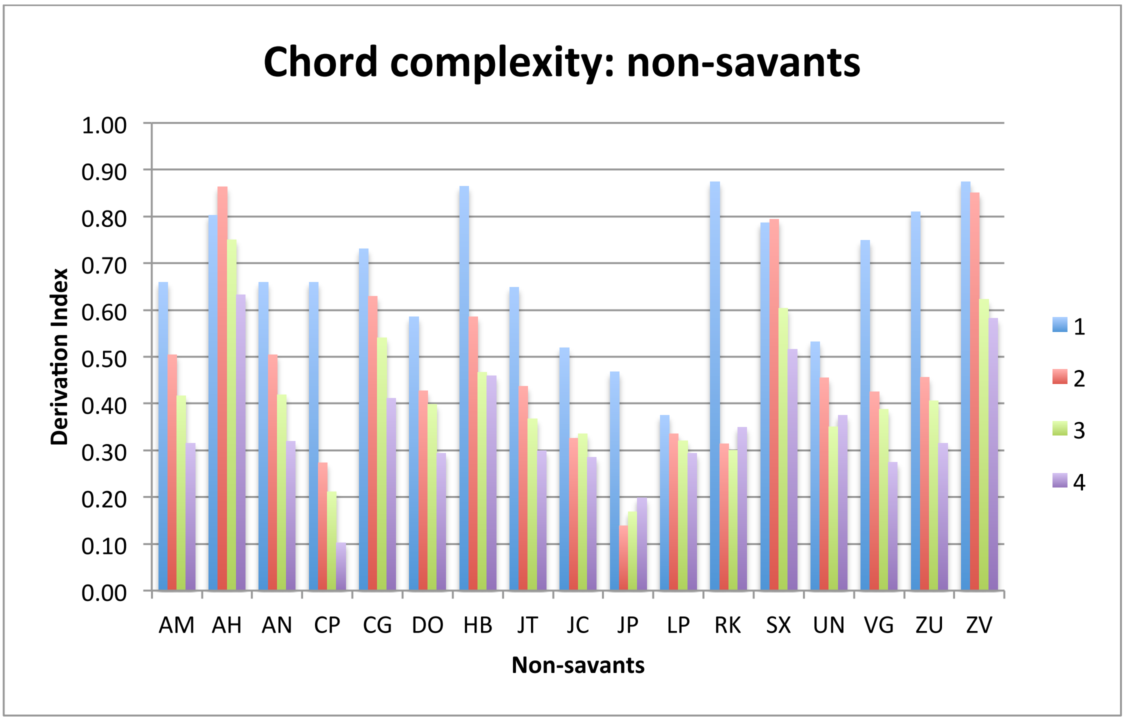


Fig. 3.25 Scores for the non-savant comparison group for the different complexity levels.

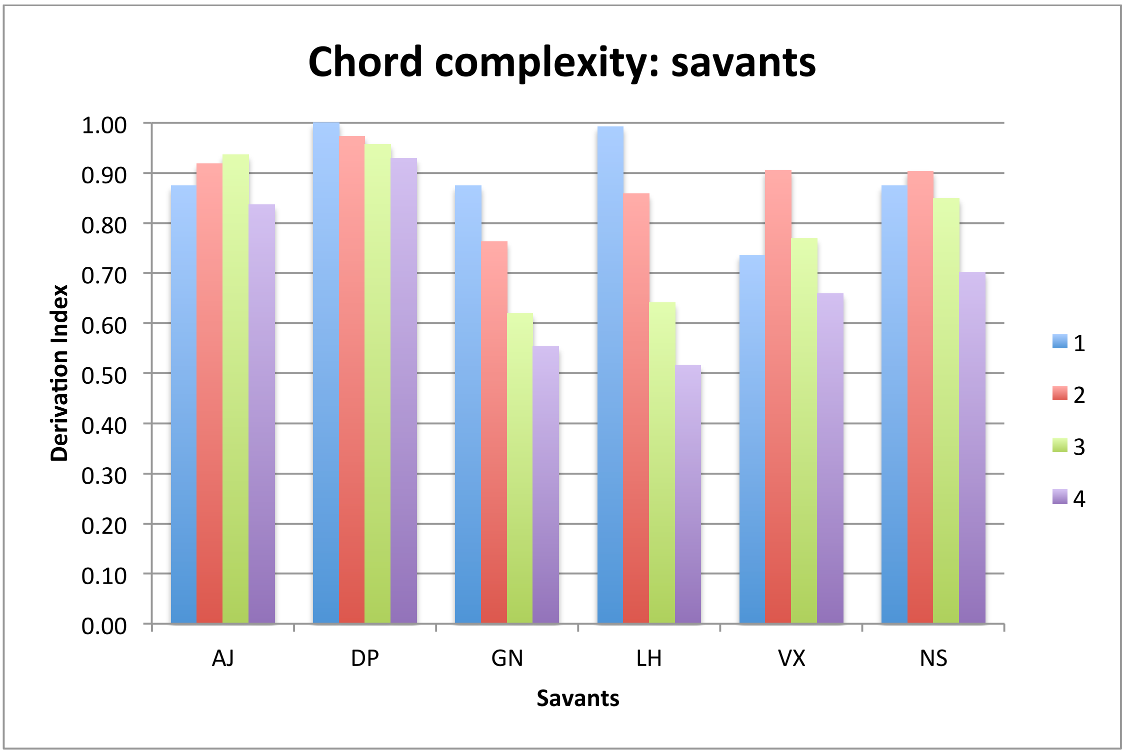


Fig. 3.26 Scores for the savant group for the different complexity levels.

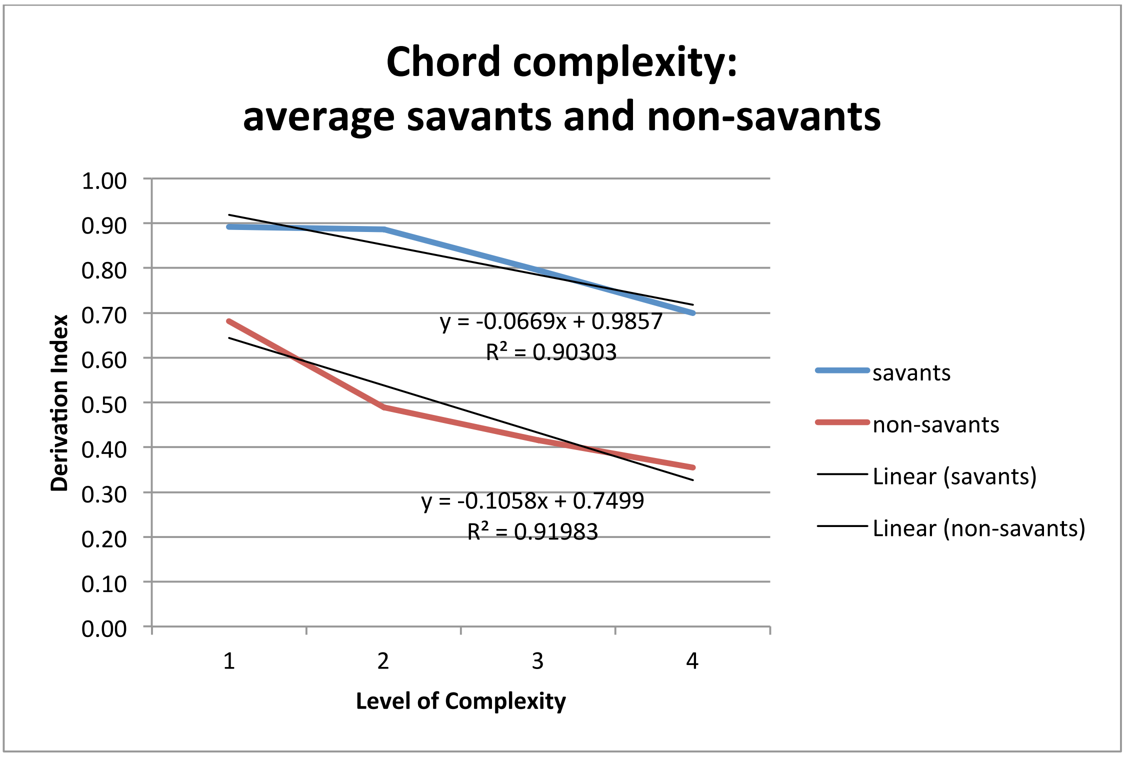


Fig. 3.27 Average scores for the savant and non-savant participant groups, for the different complexity levels.

In summary:

- All participants are affected by the complexity of the chords; the accuracy of their performances is related to the harmonic complexity of the task (see Figures 3.24, 3.25 and 3.26);

- When the chords have a more complex structure they are more difficult to disaggregate;

- Based on this analysis, the savants consistently outperform the comparison group irrespective of chordal complexity (Figure 3.27), suggesting that similar strategies may be in play with both groups.

An ANOVA was not performed because there was a very wide variability within savants and non-savants group (see Figure 3.10). In paragraphs 3.6.7.1 and 3.6.7.2 analysis of individual's results will be discussed in order to evidence large amounts of inter-subject variation within both groups.

3.6.4.1 Evaluating the chordal complexity variable

Examining the results in relation to chord size and complexity indicates that these two factors may be similar (see Figures 3.13 and 3.27). Therefore the extent to which they function independently needs to be ascertained. (The initial assumption was that complexity is not directly related to chord size since a large chord can be very simple, although a small chord is unlikely to be very complicated). Table 3.15 describes the level of complexity (from 1 to 5) for each chord.

Table 3.15 Size and complexity level of the chords.

	Chord number																					
Size	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Mean**	**SD**
4	1	2	3	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	**2.1**	**0.45**
5	2	2	2	2	2	3	2	2	3	2	2	2	2	2	3	2	2	2	2	2	**2.15**	**0.37**
6	4	3	2	4	3	4	2	3	2	4	2	3	2	3	2	2	2	2	4	2	**2.75**	**0.85**
7	3	4	3	2	2	2	1	2	4	4	4	4	2	2	2	4	4	2	3	2	**2.8**	**1.01**
8	3	4	2	2	5	2	5	5	2	2	2	2	5	4	2	5	4	4	5	5	**3.5**	**1.36**
9	5	4	3	5	5	2	5	5	3	2	5	3	5	3	2	2	5	3	4	2	**3.65**	**1.27**

The *x-axis* in Figure 3.28 gives the six different groups of chord, divided by size, while the *y-axis* shows the mean complexity for each group. The graph shows how complexity increases with the chord size, in a linear relationship.

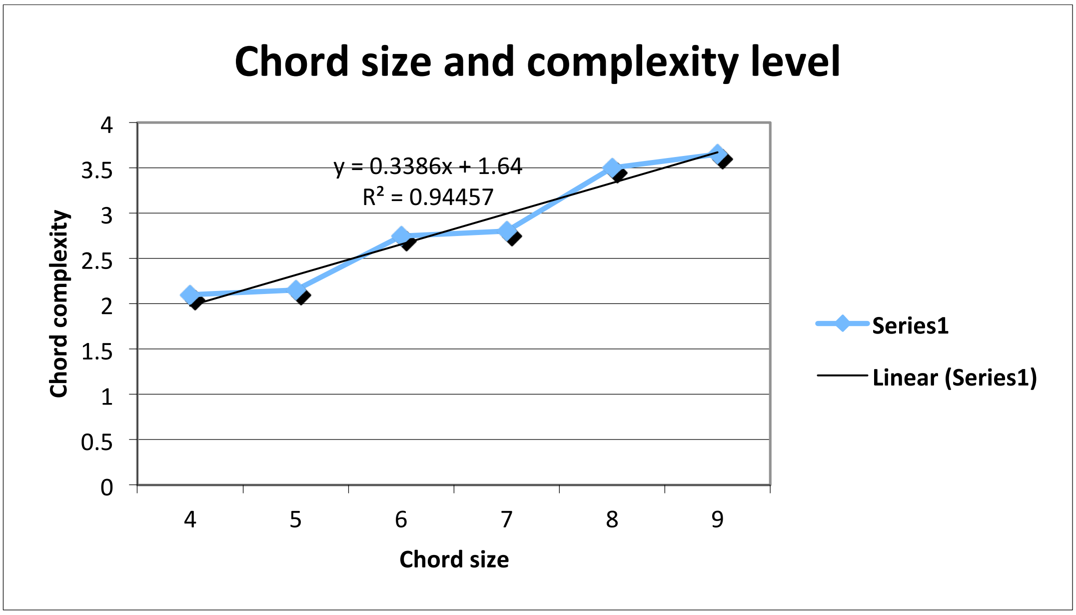


Fig. 3.28 Chord complexity in relation to chord size.

Another way of looking at this is to consider the product of size and complexity, which increases in proportion to chord size.

Table 3.16 Growth of complexity in chords.

Size*Complexity	Size*Complexity ratio through the task
8.4	1
10.75	1.3
16.5	2.0
19.6	2.3
28	3.3
32.85	3.9

In Figure 3.29 the *x-axis* maps chord size and the *y-axis* the complexity ratio between chords. There is a linear increase in the difficulty of the task as measured by size and complexity.

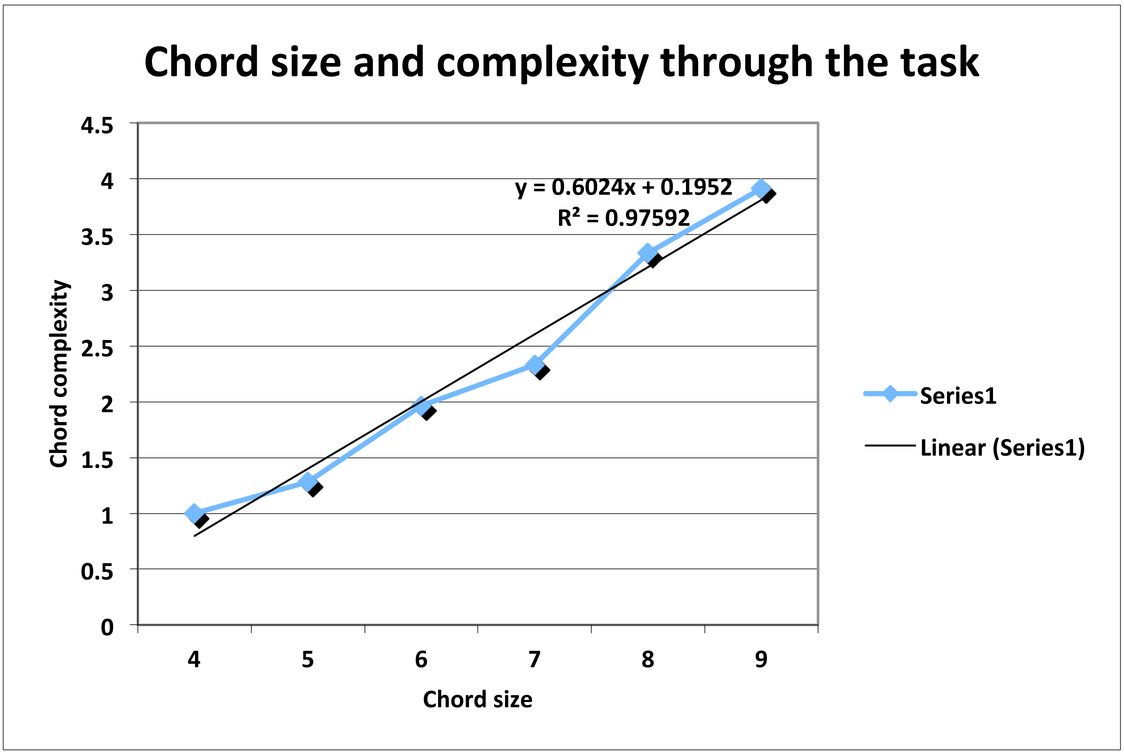


Fig. 3.29 Size by complexity ratio through the task.

Although it is theoretically possible to have small chords that are complex and large chords, that are simple, the most likely scenario (and the one that pertains to the stimuli in this experiment) is that as size increases, so does complexity (see Figures 3.28 and 3.29). Therefore, the complexity of this group of chords cannot be considered as an independent variable.

3.6.5 Analysis of performances by tonal and atonal clusters

Tonal and non-tonal features are an alternative classification for the stimuli in order to analyse the data from a different perspective. The chords in the tonal group are based on 'tertian' harmonies (built up from 3^{rds}) typical of Western harmony of the 'common practice' period; the non-tonal harmonies are constructed on other principles, such as regular (or sometimes irregular) patterns of tones and semitones (see Figures 3.30 and 3.31 for details).

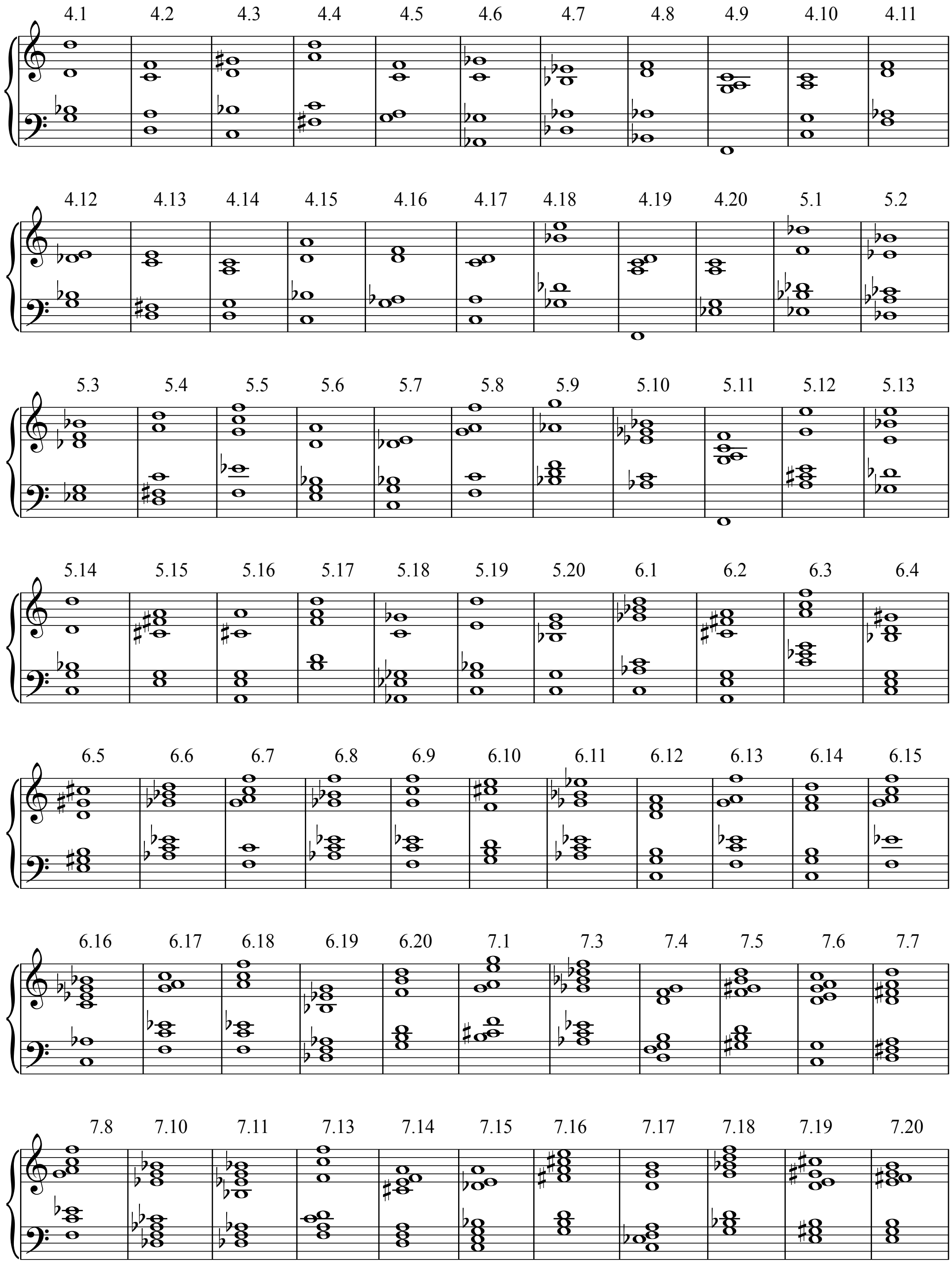


Fig. 3.30 Tonal chords.

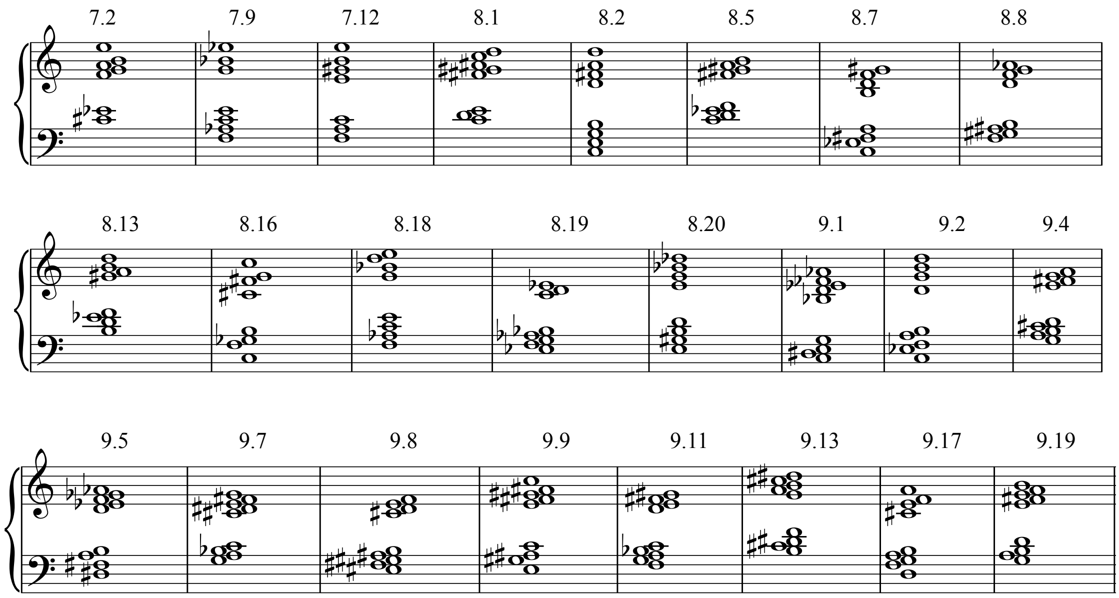


Fig. 3.31 Non-tonal chords.

The aim is to measure the differences in accuracy achieved by each participant in relation to the tonal and non-tonal categories.

As the graph shows (Figure 3.32), participants achieve higher accuracy for tonal compared to non-tonal chords. Once more, the savants display more accuracy than the non-savants (see Figures 3.33 and 3.34).

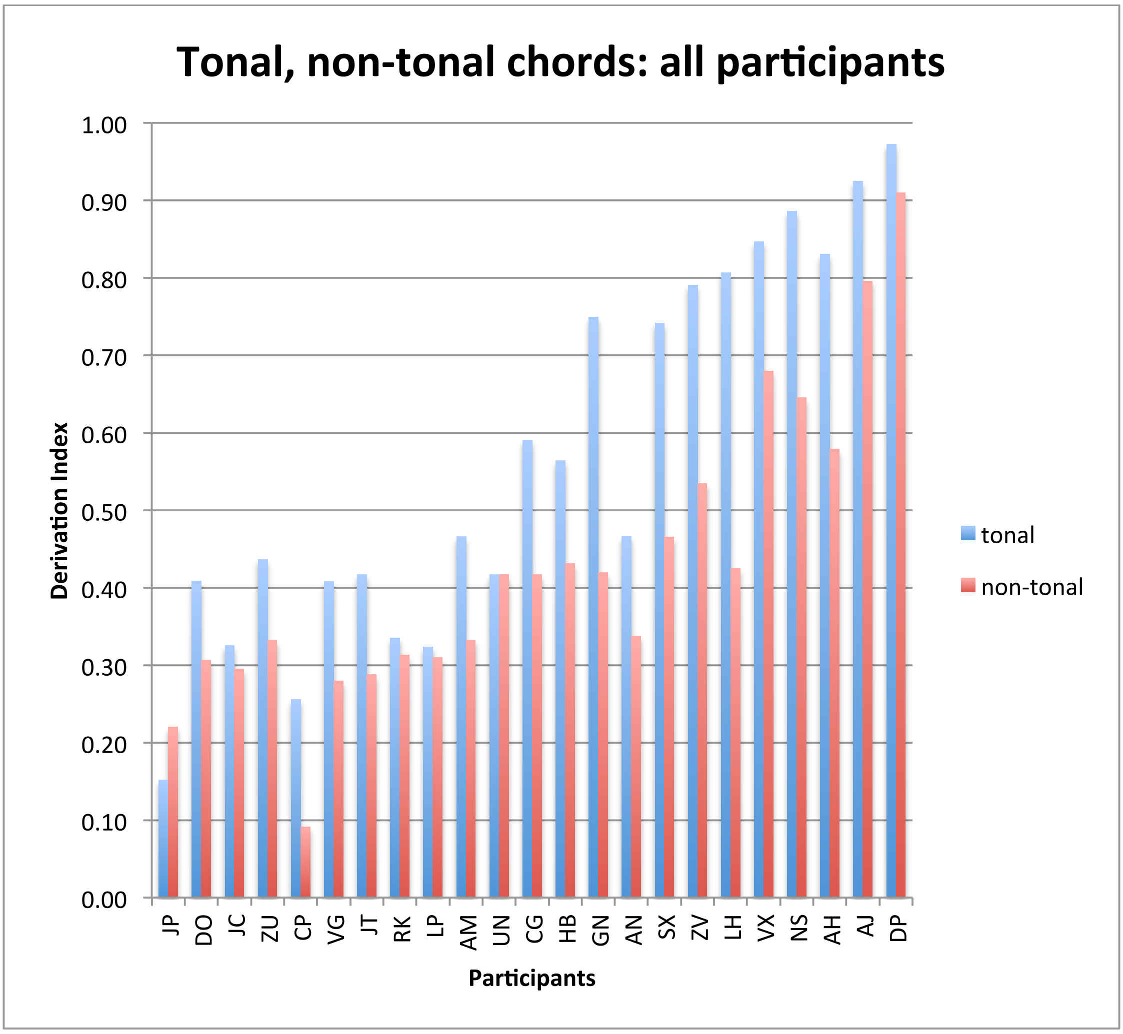


Fig. 3.32 Scores for all participants for tonal and non-tonal chords.

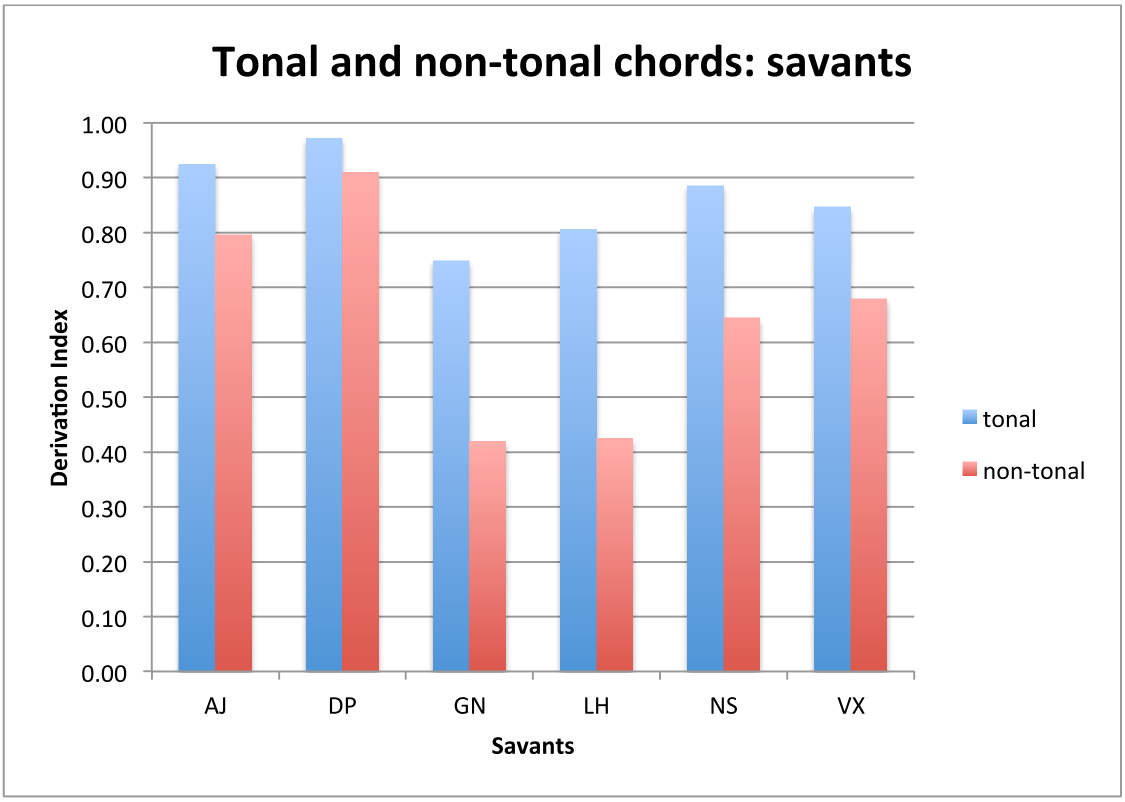


Fig. 3.33 Scores for the savant group for tonal and non-tonal chords.

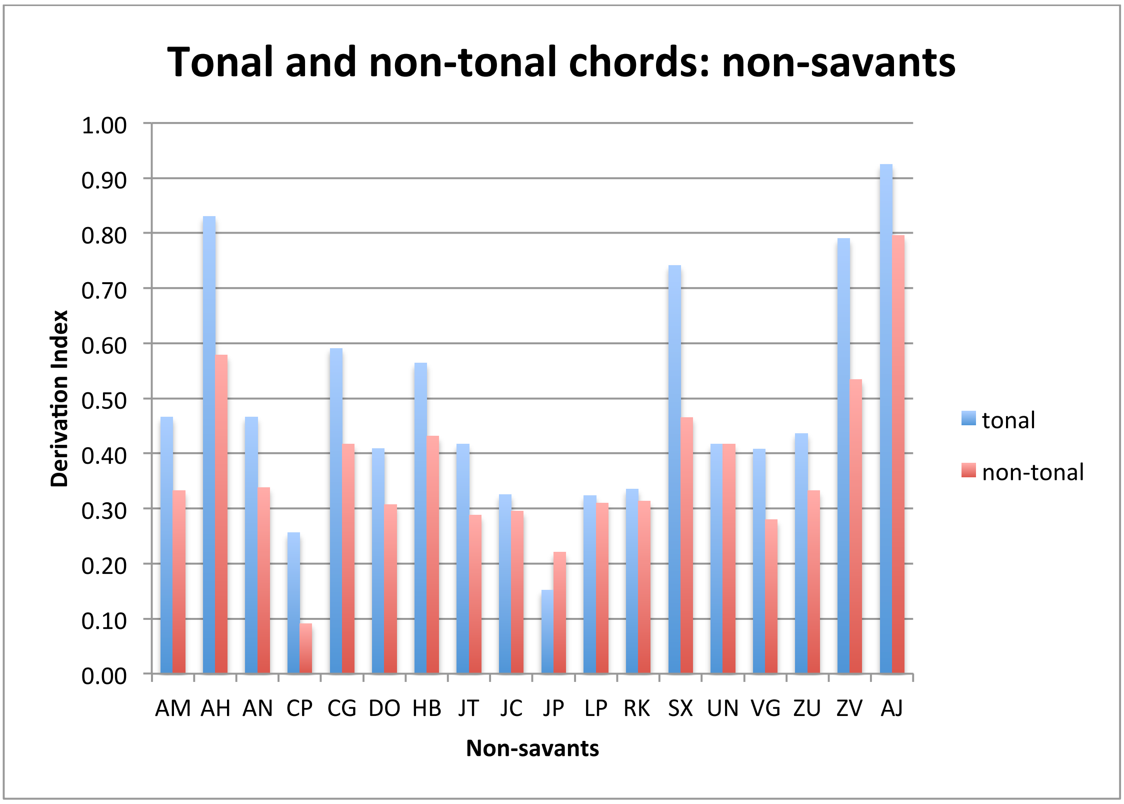


Fig. 3.34 Scores for the non-savant group for tonal and non-tonal chords.

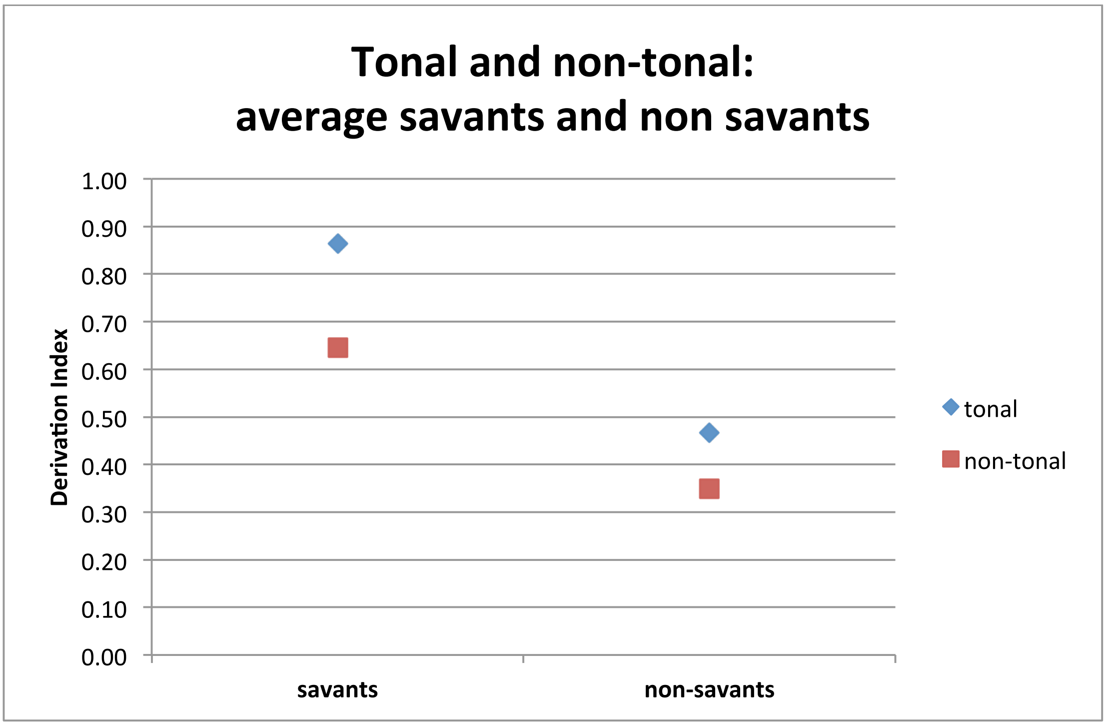


Fig. 3.35 Average scores for savant and non-savant comparison groups for tonal and non-tonal chords.

In summary:

- The graphs show that the chords being tonal or non-tonal affects all the participants' scores; on average both groups perform better (with higher scores) for tonal chords, compared to non-tonal chords. This could suggest that both groups are more familiar with tonal rather than non-tonal music. Even DP (the highest-scoring participant) performs better for tonal chords (*cf.* Chapter 9, Ockelford, 2012);

- This confirms that tonal chords are easier to disaggregate, and therefore to replicate;

- Comparing the mean scores of the savants and non-savants (see Figure 3.35) shows that savants perform better than non-savants;

- Both groups perform better with tonal than non-tonal chords, with the savants and a few of the comparison participants consistently outperforming the others in the comparison group. This suggests that the savants and the most successful comparison subjects adopt similar strategies in their approach to the task, which are more effective than those used by the other comparison participants (see Figure 3.32).

3.6.6 Analysis of performances by chordal structure: top, inner and bottom notes

Top, inner and bottom notes offered another criterion by which the data could be analysed. Each stimulus is split into its component notes, which are categorised as being at the top (the highest note), middle (inner notes) or bottom (the lower note) of the chord. Participants' responses are assessed for their accuracy for single notes, to allow insight into the strategies used in attempting the task.

Figure 3.36 illustrates that participants achieve different accuracy scores for the top, inner and bottom notes of the chord, and that there are also variations between participants. As Figure 3.37 shows, the savants achieve a higher percentage of accuracy for the bottom notes compared to the top notes; on the contrary the non-savant comparison group sometimes attains more accuracy for the top note and sometimes for the bottom (see Figure 3.38).

It is evident that two strategies are applied by the comparison group – one strategy which is 'savant like' and one which is not.

Figures 3.39, 3.40 and 3.41 below show clearly that those who correctly replicate the bottom note perform with greater accuracy overall, suggesting that getting the bottom note correct (or 'listening from the bottom note up') is a more successful chordal disaggregation strategy than 'listening from the top down'.

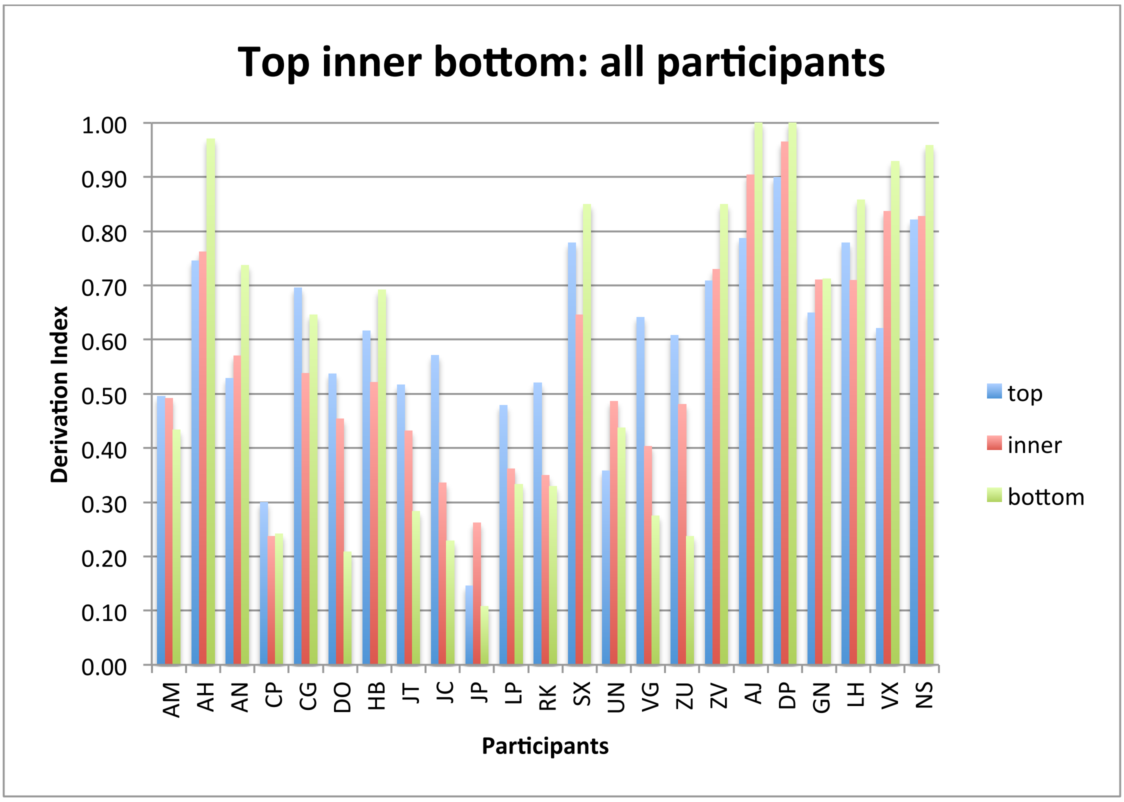


Fig. 3.36 Scores for all participants for top inner bottom notes.

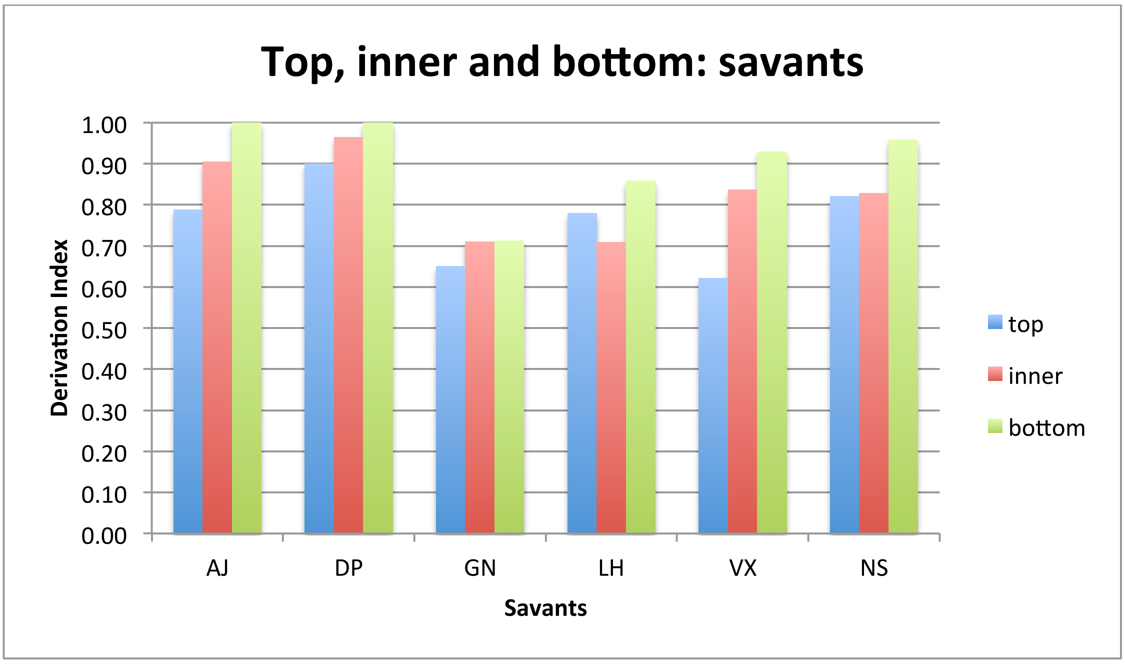


Fig. 3.37 Scores for the savant group for top, inner and bottom notes.

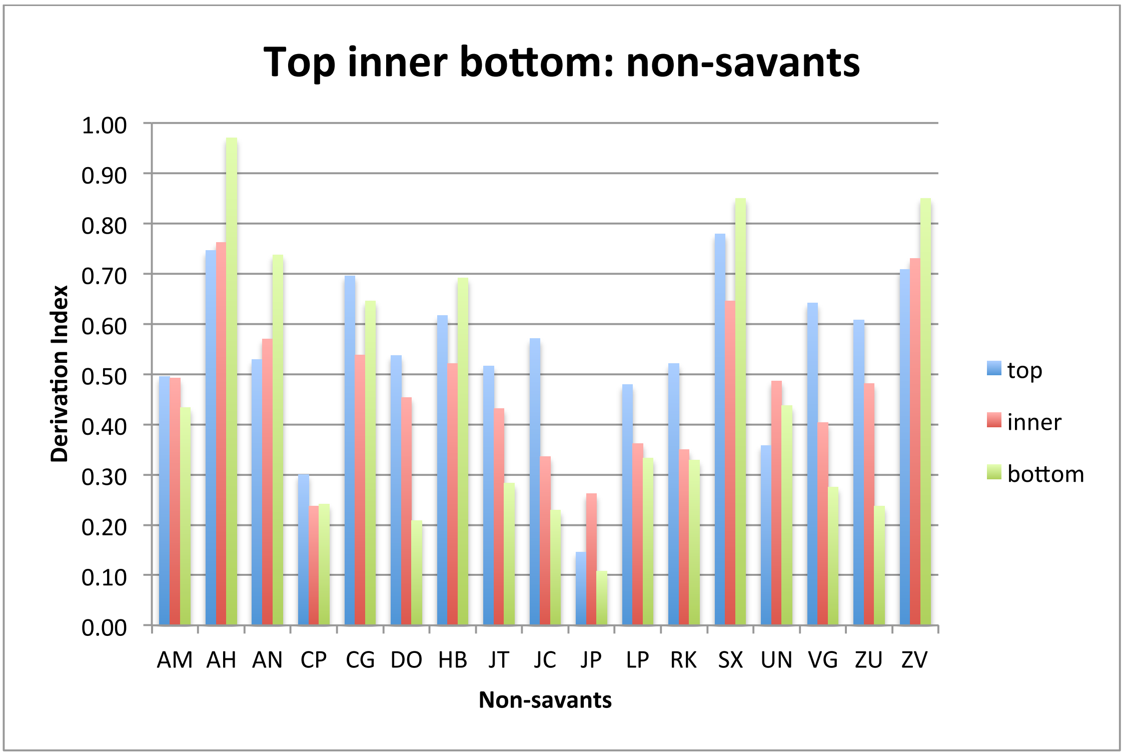


Fig. 3.38 Scores for the non-savant group for top, inner and bottom notes.

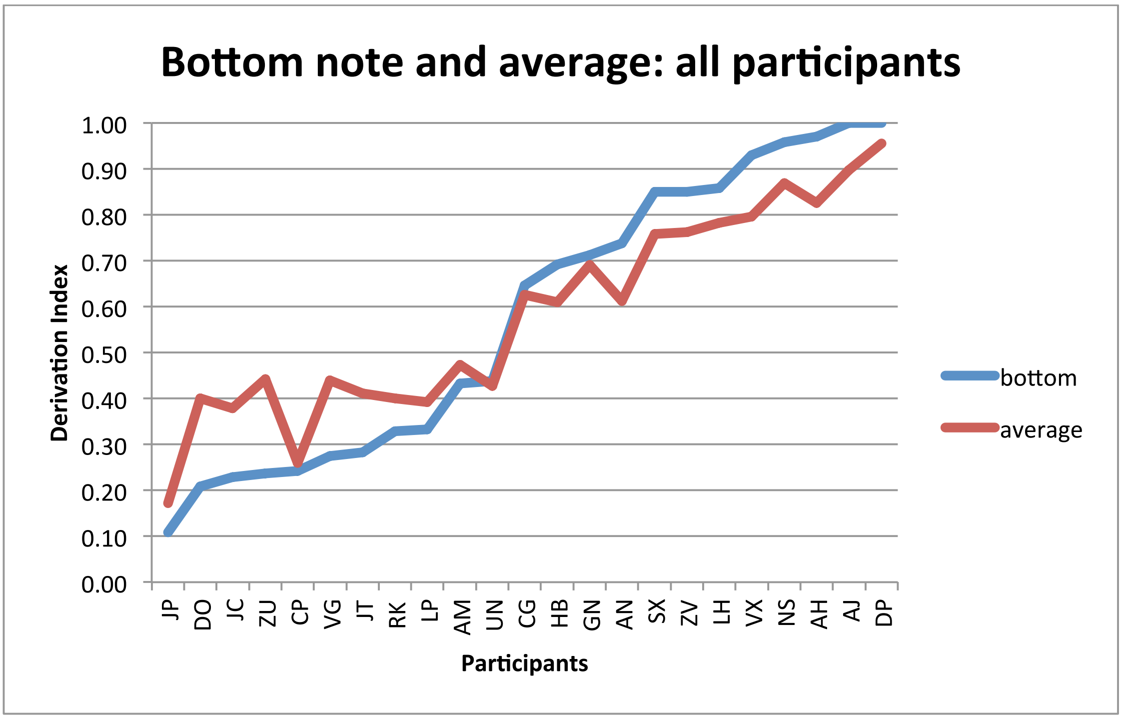


Fig. 3.39 Savants' and non-savants' accuracy for the bottom note of each chord, and overall average accuracy.

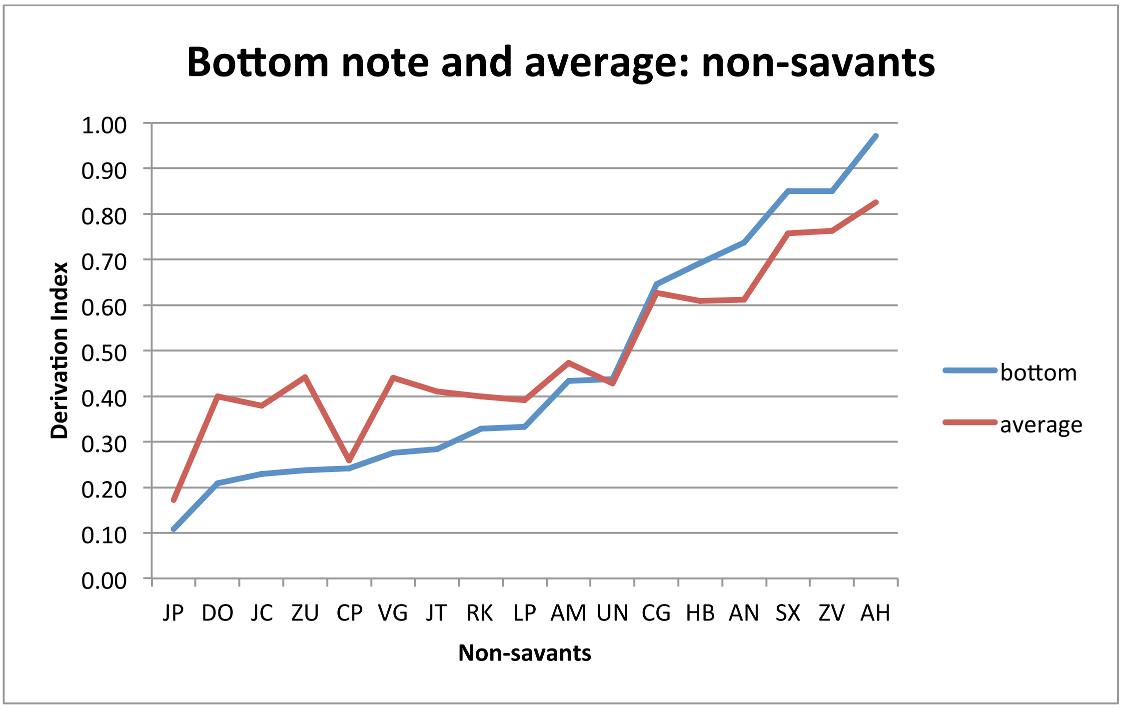


Fig. 3.40 Non-savants' accuracy for the bottom note of each chord and overall average accuracy.

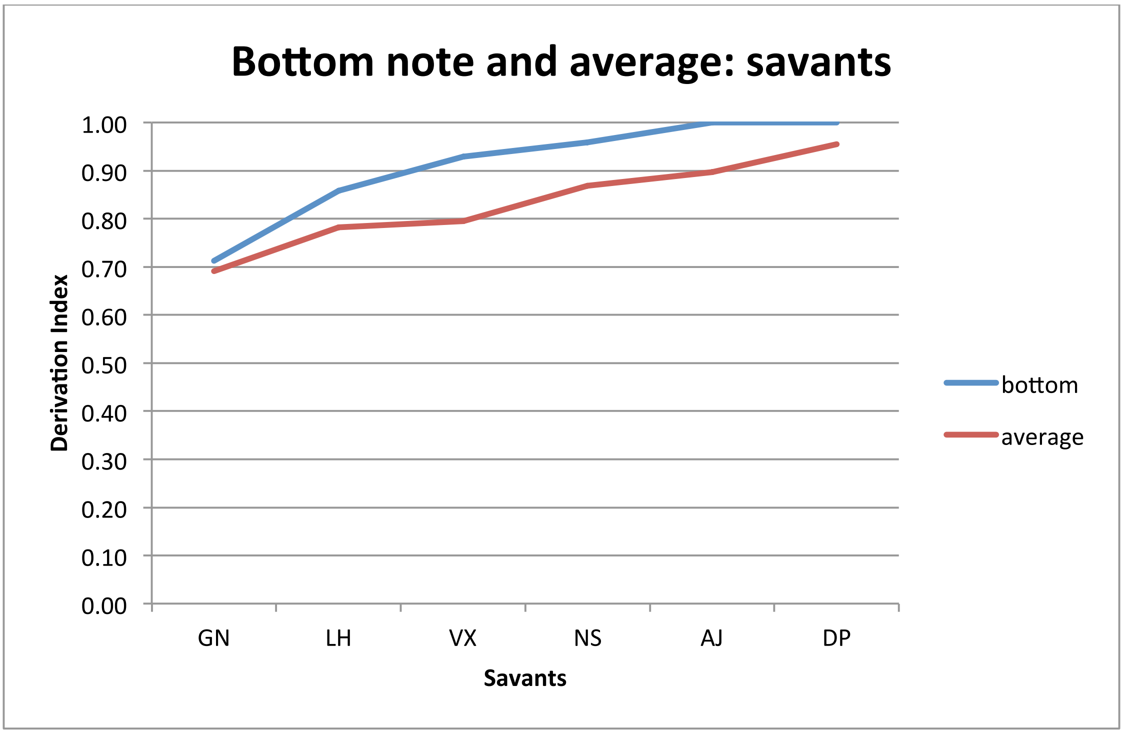


Fig. 3.41 Savants' accuracy for the bottom note of each chord, and overall average accuracy.

In summary:

- The graphs show that savants and five of the non-savants are more accurate with the 'bottom' (bass) notes, whereas the remaining non-savants are more accurate with the top notes (Figures 3.37 and 3.38). This could indicate that the savants and some of the non-savants adopt similar listening strategies that are more interrogative of harmonic structure;

- Therefore, this would suggest that they have a different approach to hearing, grasping the basic structure (harmony) and then attempting to reproduce the complete chord. On the contrary, the majority of the non-savants attain more accuracy for the top note (which often corresponds to the melody); in musical terms this is the more immediate or 'surface' sound;

- All the savants (6 out of 6) attain higher accuracy for the bottom notes. On the other hand, the non-savant comparisons achieve various scores:
    - 5 out of 17 attain higher scores for the bottom notes (similar to savants);
    - 12 out of 17 obtain higher scores for the top or inner notes.

- The non-savants who get the bottom note correct are those who achieve greater accuracy overall;

- The important point identified throughout these analyses is that savants seem to adopt a particular strategy in disaggregating chords, which serves them well (the 'bottom up' strategy) and that some of the comparison subjects either adopt this strategy (in which case they are relatively successful) or they adopt a 'top down' strategy, in which case they are less successful;

- In other words, two strategies are identified: a ‘top down’ listening approach, adopted by some (the least successful) of the non-savant group, and a ‘bottom up’ approach, which all the savants and the most successful of the comparison group adopt. This is clearly illustrated in Figure 3.40;

- The highest scores were attained by those who got the bottom note correct (see Figures 3.39, 3.40 and 3.41).

3.6.7 Analysis of example individual cases: NS, AH and CP

In addition to the broad considerations discussed above, the following analysis of individual cases will allow greater insight into the processes involved in the task. It is possible that just looking at averages may exclude some important details, as significant findings are often in the details of participants’ responses.

Therefore, the model created by Ockelford (2012) is extended and used to analyse individual performances. In his book *Applied Musicology* (2012) Ockelford created this model to describe and analyse the responses of three of the participants (the savants DP and AJ, and SX, a non-savant comparison), from a larger study.

Applying the aforementioned protocol, three cases will be analysed here, involving the responses of one savant (NS) and two non-savant comparison participants (AH and CP).

3.6.8 NS’s capacity for disaggregating chords – the results of testing

Figure 3.42 illustrates NS’s results. Where the chords are smaller, the accuracy of the results is greater. Table 3.17 gives the mean scores as well as the standard deviations.

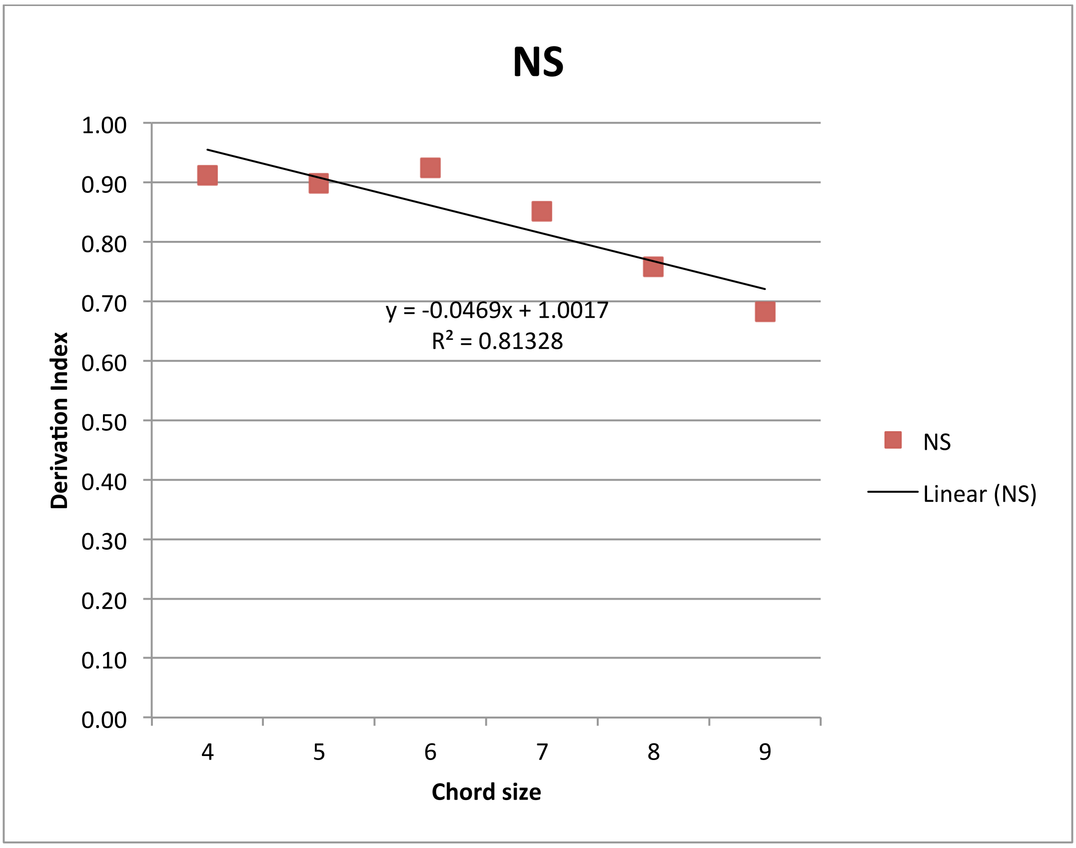


Fig. 3.42 NS's accuracy results.

Table 3.17 NS's weighted mean scores and standard deviations.

Size of the chord	Z	SD
4	0.91	0.12
5	0.90	0.14
6	0.92	0.08
7	0.85	0.14
8	0.76	0.16
9	0.68	0.20

Tables 3.18 to 3.23 show detailed results of NS's performance for each set of chords. The symbol **#R** in the Tables (3.18 to 3.23, 3.26 to 3.31 and 3.34 to 3.39), represents the number of notes played for each stimulus heard, **#C** corresponds to the number of correct responses that NS got, **R** stands for the percentage of the accuracy, **P** is the result of the probability formula that was created for the appropriate combination of the number of notes played and the number of notes played correctly, and **Z** is the weighted score. In NS's case, the differences between R and Z are minor, since the probabilities of such high levels of accuracy

occurring by chance are very small. Figures 3.43a and 3.43b show the stimuli followed by NS's responses from 4 to 9 note chords.

Fig. 3.43 (a) NS's responses to four-, five-, six- and seven-note chordal stimuli.

Fig. 3.43 (b) NS's responses to seven-, eight- and nine-note chordal stimuli.

3.6.9 NS's four-note chords

At the four-note level (see Table 3.18) NS adds notes on four occasions (4.4, 4.5, 4.7 and 4.18) and makes seven omissions (4.1, 4.6, 4.10, 4.15, 4.16, 4.17 and 4.18).

With regard to additions, on three occasions (4.4, 4.5, 4.7) he adds extra pitches to the stimuli that were presented, producing three chords of five notes. NS's additions invariably repeat a pitch-class that was present in the stimulus at a different octave (for example, in 4.4 he repeated D in the 4th octave that was already present in the stimulus in the 5th). These extra notes do not change the harmonic nature of the chord (Ockelford, 2012). For example, chord 4.4 is 'D7', and it remains D7 with the addition of another D. Hence NS's additions reflect an intuitive understanding of Western harmony.

The notes he adds do not have a significant influence on the probability of his response occurring by chance (p = 0.0004; see Table 3.6). Therefore the 'raw' (**R**) and 'weighted' (**Z**) scores are almost the same, implying that there is only a very small chance that he repeats the notes accidentally. With regard to the omissions, five are of the top note (4.1, 4.6, 4.10, 4.17 and 4.18) and two in the inner parts of the chords (4.15 and 4.16). Again, these have a negligible impact on the probability that his responses occur by chance (p = 0.0017).

Table 3.18 NS's chordal disaggregation data for four-note chords, with P and Z scores given (assuming #U=25).

4 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
4.1	3	3	0.75	0.0017	0.75
4.2	4	4	1.00	0.0001	1.00
4.3	4	4	1.00	0.0001	1.00
4.4	5	4	1.00	0.0004	1.00
4.5	5	4	1.00	0.0004	1.00
4.6	3	3	0.75	0.0017	0.75
4.7	5	4	1.00	0.0004	1.00
4.8	4	4	1.00	0.0001	1.00
4.9	4	4	1.00	0.0001	1.00
4.10	3	3	0.75	0.0017	0.75
4.11	4	4	1.00	0.0001	1.00
4.12	4	4	1.00	0.0001	1.00
4.13	4	4	1.00	0.0001	1.00
4.14	4	4	1.00	0.0001	1.00
4.15	3	3	0.75	0.0017	0.75
4.16	3	3	0.75	0.0017	0.75
4.17	3	3	0.75	0.0017	0.75
4.18	4	3	0.75	0.0066	0.75
4.19	4	4	1.00	0.0001	1.00
4.20	4	4	1.00	0.0001	1.00
Mean	**3.85**	**3.65**	**0.91**	**0.0010**	**0.91**
				SD	**0.12**

3.6.10 NS's five-note chords

In five-note chord responses (Table 3.19) there are additions (5.2, 5.6, 5.11, 5.13, 5.14, 5.16, 5.17, 5.19 and 5.20) and omissions (5.4, 5.8, 5.9, 5.12, 5.13, 5.15 and 5.18). On two occasions (chord 5.4 and 5.17), NS plays the correct pitch class but in the wrong octave giving an error score of 4.5 in one case and 3.5 in the other (as here he also omits one note). His additions are always coherent with the pitches in the chord; for example, in chord 5.2, he doubles the pitch A# that was originally the bottom note of the stimulus (in the 4th octave), playing it again at the lower octave (3rd); in addition, he doubles the pitch D# that was at the 4th octave playing it in the 3rd octave too.

A similar principle is applied for chords 5.6, 5.9 5.11, 5.14, 5.16 and 5.20. In chord 5.17, NS plays a note (A) at the wrong octave (in the 3rd instead of the 4th) and an added pitch (C4) appears briefly in what sounds like a slip of the finger. In 5.19 two notes are doubled twice: D, which is in the 5th octave in the stimulus, is played in the 4th octave, and G, which is in the stimulus in the 3rd, he doubles in the 4th octave.

With regard to the omissions, in 5.8 he omits C, in 5.9 A♭ and F, and in 5.12 he omits E4 and E5 and plays B4. In 5.15 he omits D♭ and in 5.18 G♭. All the omitted notes are located in the inner parts of the chords.

Table 3.19 NS's chordal disaggregation data for five-note chords, with P and Z scores given (assuming #U=25).

5 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
5.1	5	5	1.00	0.0000	1.00
5.2	7	5	1.00	0.0004	1.00
5.3	5	5	1.00	0.0000	1.00
5.4	4	3.5	0.70	0.0081	0.69
5.5	5	5	1.00	0.0000	1.00
5.6	7	5	1.00	0.0004	1.00
5.7	5	5	1.00	0.0000	1.00
5.8	4	4	0.80	0.0004	0.80
5.9	4	3	0.60	0.0158	0.59

5.10	5	5	1.00	0.0000	1.00
5.11	6	5	1.00	0.0001	1.00
5.12	4	3	0.60	0.0158	0.59
5.13	5	4	0.80	0.0019	0.80
5.14	7	5	1.00	0.0004	1.00
5.15	4	4	0.80	0.0004	0.80
5.16	6	5	1.00	0.0001	1.00
5.17	6	4.5	0.90	0.0046	0.90
5.18	4	4	0.80	0.0004	0.80
5.19	7	5	1.00	0.0004	1.00
5.20	6	5	1.00	0.0001	1.00
Mean	**5.3**	**4.5**	**0.90**	**0.0025**	**0.90**
				SD	**0.14**

3.6.11 NS's six-note chords

In response to the six-note chords, NS makes several additions (6.1, 6.2, 6.5, 6.7, 6.12, 6.13, 6.15, 6.17, 6.18 and 6.20) and omits a number of notes (6.1, 6.6, 6.8, 6.11, 6.14, 6.16 and 6.20).

With regard to additions, in chord 6.2 NS doubles the A that was in the stimulus at the 2nd octave, also playing it in the 3rd octave (therefore without creating any harmonic changes, and maintaining the same harmonic structure). In chord 6.5 NS adds an F# in the 4th octave, which is not present in the stimulus, and which forms the 9th of the chord. In 6.7 there is a repetition of the G present in the stimulus at the 4th octave in the lower octave (3rd); he also adds D in the 4th octave, which functions as an added 6th, and therefore does not change the basic structure of the harmony. In 6.12 NS adds a 3rd (E) in the 3rd octave without changing the nature of the chord. In the chords 6.13, 6.15, 6.17, 6.18 one or two notes present in the stimulus are repeated in the higher or lower octave, or both.

None of the omissions changes the underlying structure of the harmonies: in 6.6, 6.8 and 6.11, the 5^{ths} are omitted, in 6.16 the 7th is absent and in 6.14 the 9th is omitted.

Table 3.20 NS's chordal disaggregation data for six-note chords, with P and Z scores given (assuming #U=25).

6 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
6.1	6	5	0.83	0.0006	0.83
6.2	7	6	1.00	0.0000	1.00
6.3	6	6	1.00	0.0000	1.00
6.4	6	6	1.00	0.0000	1.00
6.5	7	6	1.00	0.0000	1.00
6.6	5	5	0.83	0.0001	0.83
6.7	8	6	1.00	0.0002	1.00
6.8	5	5	0.83	0.0001	0.83
6.9	6	6	1.00	0.0000	1.00
6.10	6	6	1.00	0.0000	1.00
6.11	5	5	0.83	0.0001	0.83
6.12	7	6	1.00	0.0000	1.00
6.13	8	5	0.83	0.0054	0.83
6.14	5	5	0.83	0.0001	0.83
6.15	7	6	1.00	0.0000	1.00
6.16	5	5	0.83	0.0001	0.83
6.17	9	5	0.83	0.0114	0.82
6.18	7	6	1.00	0.0000	1.00
6.19	6	6	1.00	0.0000	1.00
6.20	6	5	0.83	0.0006	0.83
Mean	**6.35**	**5.55**	**0.93**	**0.0009**	**0.92**
				SD	**0.08**

3.6.12 NS's seven-note chords

NS makes additions to each of the following chords: 7.1, 7.2, 7.4, 7.11, 7.12, 7.13, 7.17 and 7.18. He omits notes in 7.1, 7.2, 7.3, 7.5, 7.6, 7.9, 7.11, 7.14, 7.15, 7.17, 7.18, 7.19 and 7.20.

In 7.1 NS adds a 3rd and a 9th, thus maintaining the tonal structure. In 7.4 he adds A in the 3rd octave, again adding a 9th. In 7.2 (cluster) NS adds C4, in 7.12 (cluster) he adds G3 and in 7.13 NS adds E4, these additions, which are very short, are probably due to slips of the finger.

With regard to omissions, in 7.1 NS omits G twice (one the top and one an inner note) and plays D♭ in the 4th instead of the 3rd octave. In 7.3 he omits the 5th of the chord. In 7.5, 7.6, 7.14, 7.19 and 7.20 the omitted notes had already been played in a different octave and therefore do not modify the harmonic structure of the chord. In 7.9 E♭ and B♭ (the top and an inner note) are omitted, and in 7.15 NS omits the top note without altering the structure.

Table 3.21 NS's chordal disaggregation data for seven-note chords, with P and Z scores given (assuming #U=25).

7 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
7.1	6	4.5	0.64	0.0210	0.63
7.2	7	5	0.71	0.0051	0.71
7.3	6	6	0.86	0.0000	0.86
7.4	8	7	1.00	0.0000	1.00
7.5	5	5	0.71	0.0004	0.71
7.6	6	6	0.86	0.0000	0.86
7.7	7	7	1.00	0.0000	1.00
7.8	7	7	1.00	0.0000	1.00
7.9	5	5	0.71	0.0004	0.71
7.10	7	7	1.00	0.0000	1.00
7.11	7	6	0.86	0.0000	0.86
7.12	8	7	1.00	0.0000	1.00
7.13	8	7	1.00	0.0000	1.00
7.14	6	6	0.86	0.0000	0.86
7.15	6	6	0.86	0.0000	0.86
7.16	7	7	1.00	0.0000	1.00
7.17	7	4	0.57	0.0547	0.54
7.18	7	6	0.86	0.0000	0.86
7.19	6	6	0.86	0.0000	0.86
7.20	5	5	0.71	0.0004	0.71
Mean	**6.55**	**6**	**0.85**	**0.0041**	**0.85**
				SD	**0.14**

3.6.13 NS's eight-note chords

NS makes additions to 8.2, 8.5, 8.6, 8.7, 8.9, 8.11, 8.16, 8.18 and 8.20 and omissions in 8.1, 8.2, 8.5, 8.6, 8.7, 8.8, 8.10, 8.11, 8.12, 8.13, 8.14, 8.15, 8.16, 8.17, 8.18 and 8.19.

In 8.5 (cluster) NS adds one note (D) that is already in the stimulus at a different octave and changes the octave of the A4, playing it in the 3rd octave. He also adds three new notes. The original cluster (8.5) has a regular structure (alternating tones and semitones – effectively a composite of two diminished 7th chords) and it seems that NS emulates some though not all of its characteristics; he produces 3 intervals of a semitone, just as they are in the stimulus, and three minor 3rds that produce a diminished 7th chord starting on D. He also produces a diminished 7th chord starting on B♭ (rather than C). Therefore, there are structural similarities with the original stimulus. In 8.2 (cluster), 8.6, 8.9 and 8.11, NS adds a note that was already played in the chord alongside other additional notes, such as G in 8.9 and C in 8.11, without altering the chords' structures. In 8.7 (a cluster) he adds G, slightly modifying the chord. In 8.16, which comprises a cluster built on 4ths, two semitones and a tone, NS adds notes (A, D and E), which depart from this structure. In 8.20, he adds C, G♭ and B♭, intercalating notes between the 3rds in the original.

With regard to the omissions, in chords 8.1, 8.6, 8.10, 8.11, 8.12, 8.14, 8.15, 8.16, 8.17 and 8.19, besides omitting and playing some notes at a different octave (e.g. in 8.16 and 8.19), NS omits notes that are doubled at the octave in the stimulus. In 8.5, 8.7, 8.8, 8.13, 8.18 and 8.20 (all of them clusters). The nature of the omissions do not modify the structure of the chord although the notes omitted are not present in other parts of the chord.

Table 3.22 NS's chordal disaggregation data for eight-note chords, with P and Z scores given (assuming #U=25).

8 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
8.1	7	7	0.88	0.0000	0.87
8.2	8	7	0.88	0.0001	0.87
8.3	8	8	1.00	0.0000	1.00
8.4	8	8	1.00	0.0000	1.00
8.5	9	4.5	0.56	0.1386	0.48
8.6	7	6	0.75	0.0010	0.75
8.7	7	6	0.75	0.0010	0.75
8.8	6	5.5	0.69	0.0028	0.69
8.9	10	8	1.00	0.0000	1.00
8.10	6	6	0.75	0.0002	0.75
8.11	8	6	0.75	0.0035	0.75
8.12	6	6	0.75	0.0002	0.75
8.13	7	7	0.88	0.0000	0.87

8.14	7	7	0.88	0.0000	0.87
8.15	6	6	0.75	0.0002	0.75
8.16	10	4.5	0.56	0.1855	0.46
8.17	7	6	0.75	0.0010	0.75
8.18	8	4	0.50	0.1540	0.42
8.19	5	5	0.63	0.0011	0.62
8.20	9	6	0.75	0.0093	0.74
Mean	**7.45**	**6.18**	**0.77**	**0.0249**	**0.76**
				SD	**0.16**

3.6.14 NS's nine-note chords

NS makes additions to each of the following chords: 9.1, 9.2, 9.9, 9.12, 9.14, 9.15, 9.16, 9.18 and 9.20. He omits notes from 9.1, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.11, 9.12, 9.13, 9.15, 9.16, 9.17, 9.19 and 9.20.

The majority of the additions are notes that have already been played at a different octave (9.9, 9.12, 9.14, 9.15, 9.16 9.17 and 9.18) except in clusters, where some additions did not accord with the stimulus, e.g. in 9.1 in which he adds F3 that was not present in the chord and plays C5 instead of C3 and in 9.2 NS adds A♭, D♭ and G♭, intercalating notes in the intervals in the original. Also in 9.5 (cluster) he adds C3 and G4, again inserting notes in between those present in the stimulus, and F3 (F was already played in the 4th octave).

In both 9.7 and in 9.8 which are clusters comprising densely packed notes separated only by tones and semitones, F4 was added (in 9.7) and, A3 and E♭4 (in 9.8) were added, changing the pattern of tones and semitones, but giving a similar harmonic 'feel'. In 9.11 (cluster) NS adds E♭4, substituting for three closely packed notes that were present in the stimulus. NS adopts a comparable strategy in 9.17 adding C4 and omitting C#4 and B3 and in 9.19 adding F4 inverting the pattern of tone-semitone in the middle of the chord.

With regard to omissions, the majority of them are either repetitions at the octave (9.1, 9.3) or omissions of notes already present in the chord (9.6, 9.7, 9.19).

In 9.4 (cluster) D and D♭ are omitted, which were not present in the stimulus. Also in 9.5 (cluster) G♭4 and G♭3 are omitted, and E♭ is omitted in the 4th octave and played in the 3rd.

Table 3.23 NS's chordal disaggregation data for nine-note chords, with P and Z scores given (assuming #U=25).

9 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
9.1	9	4.5	0.50	0.1908	0.40
9.2	10	5	0.56	0.1697	0.46
9.3	8	5.5	0.61	0.0373	0.59
9.4	6	6	0.67	0.0005	0.67
9.5	8	5	0.56	0.0652	0.52
9.6	8	8	0.89	0.0000	0.89
9.7	6	5	0.56	0.0114	0.55
9.8	6	4	0.44	0.0854	0.41
9.9	10	9	1.00	0.0000	1.00
9.10	9	9	1.00	0.0000	1.00
9.11	8	5	0.56	0.0652	0.52
9.12	9	8	0.89	0.0001	0.89
9.13	5	5	0.56	0.0024	0.55
9.14	10	7	0.78	0.0062	0.77
9.15	9	8	0.89	0.0001	0.89
9.16	9	7	0.78	0.0021	0.78
9.17	6	4	0.44	0.0854	0.41
9.18	10	6	0.67	0.0468	0.64
9.19	8	7	0.78	0.0005	0.78
9.20	9	8.5	0.94	0.0000	0.94
Mean	**8.15**	**6.33**	**0.70**	**0.0385**	**0.68**
				SD	**0.20**

3.6.15 NS summary

In examining NS's responses overall, it is evident that the additions and the omissions made, in the majority of the cases, do not alter the nature of the chords. Alterations to chords do not tend to occur since the majority of any notes added or omitted are already present at different octaves within the stimuli. In other words, NS either enhances (adding notes) or simplifies (omitting notes) without modifying the overall chord structure. Table 3.24 and Figure 3.44 display the number of omissions made by NS per each group of chords.

Table 3.24 The relative positions of the notes omitted by NS.

Chord size	No. of notes	Top note	2nd down	3rd down	4th down	Middle note	4th up	3rd up	2nd up	Bottom note	Sums
4	80	5	0	-	-	-	-	-	2	0	7
5	100	2	2	-	-	5	-	-	1	0	10
6	120	0	2	2	-	-	-	4	0	0	8
7	140	4	3	4	-	4	-	2	1	2	20
8	160	6	3	4	7	-	6	6	3	1	36
9	180	6	9	6	7	10	5	7	5	3	58
Sums	780	23	19	16	14	19	11	19	12	6	139
		Sum of lower half = 72					Sum of lower half = 48				

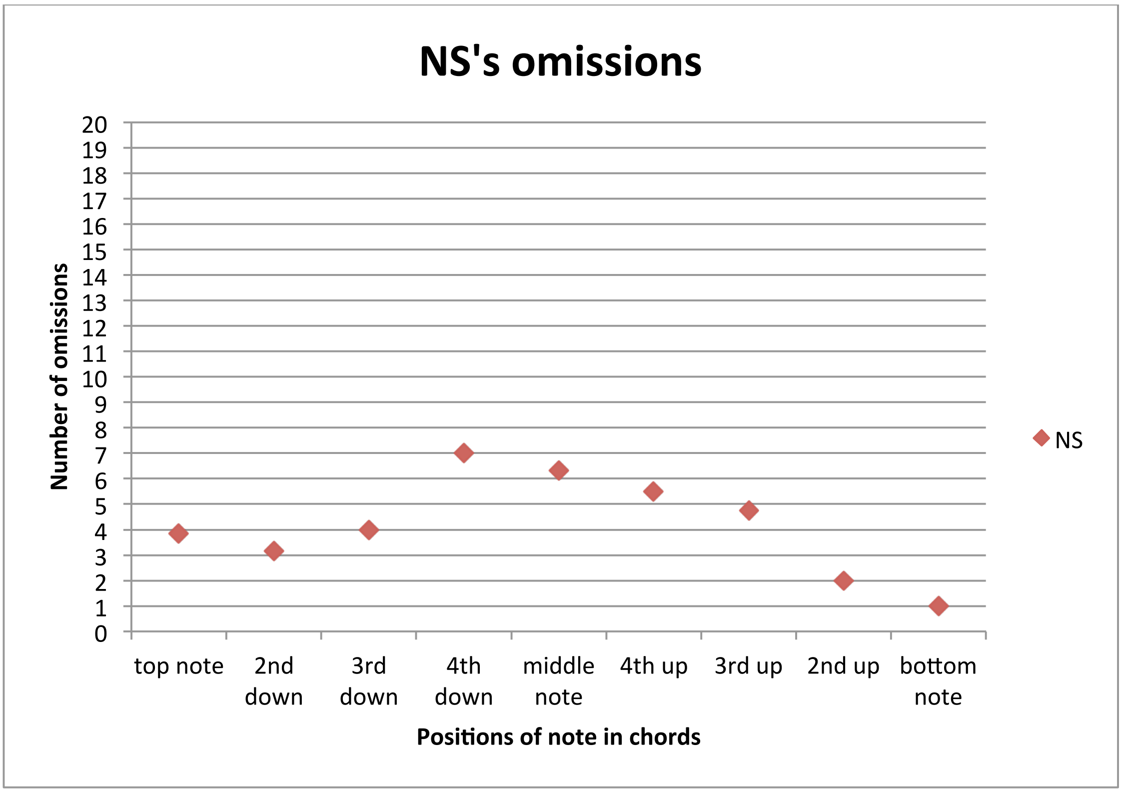


Fig. 3.44 NS's average of omissions inside the chords.

The position of the additions and omissions correspond to the general findings (Mazzeschi et al., 2011; Ockelford, 2012) that savants tend to listen to chords from the bottom up (*cf.* 3.6.3). This strategy enables a higher level of performance (see Figure 3.11) and has also been found in the most successful non-savant comparisons (*cf.* 3.6.8).

Figure 3.44 presents the omissions made by NS. He makes more omissions to the inner and top notes of the chords, while the bottom notes are omitted less often. NS's focus on the chord's bass notes suggests that, in terms of harmonic structure, he is listening from the bottom up.

3.6.16 AH's capacity for disaggregating chords – the results of testing

Figure 3.45 illustrates AH's results. As the size of the chord increases, from four notes to nine notes, AH's responses show a general decline in accuracy. Table 3.25 illustrates the scores as well as the standard deviations of these results.

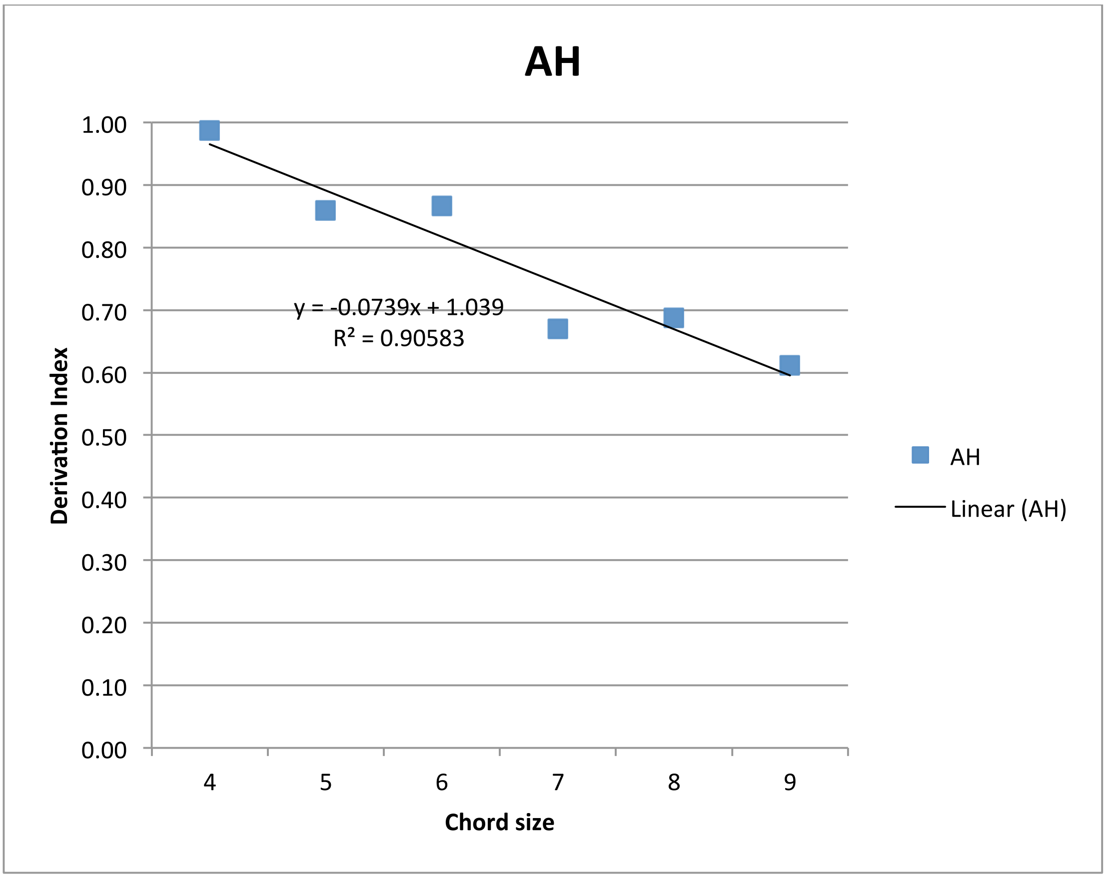


Fig. 3.45 AH's accuracy results.

Table 3.25 AH's weighted mean scores and standard deviations.

Size of the chord	Z	SD
4	0.99	0.06
5	0.86	0.13
6	0.87	0.14
7	0.67	0.22
8	0.69	0.17
9	0.61	0.25

Tables 3.26 to 3.31 illustrate the detailed results of AH's performance for each set of chords. In AH's case, the differences between R and Z are minor, since the probabilities of such high levels of accuracy occurring by chance are very small. Figures 3.46a and 3.46b show the stimuli of 4 to 9 note chords, followed by AH's performed response.

Fig. 3.46 (a) AH's responses to four-, five- six- and seven- note chordal stimuli.

Fig. 3.46 (b) AH's responses to seven-, eight- and nine-note chordal stimuli.

3.6.17 AH's four-note chords

Examining the four-note chords in detail, AH does not add additional pitches to any of the twenty chords. In terms of omissions, AH only omits the top note in chord number 4.1. However, this note was already present at the lower octave.

Table 3.26 AH's chordal disaggregation data for four-note chords, with P and Z scores given (assuming #U=25).

4 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
4.1	3	3	0.75	0.0017	0.75
4.2	4	4	1.00	0.0001	1.00
4.3	4	4	1.00	0.0001	1.00
4.4	4	4	1.00	0.0001	1.00
4.5	4	4	1.00	0.0001	1.00
4.6	4	4	1.00	0.0001	1.00
4.7	4	4	1.00	0.0001	1.00
4.8	4	4	1.00	0.0001	1.00
4.9	4	4	1.00	0.0001	1.00
4.10	4	4	1.00	0.0001	1.00
4.11	4	4	1.00	0.0001	1.00
4.12	4	4	1.00	0.0001	1.00
4.13	4	4	1.00	0.0001	1.00
4.14	4	4	1.00	0.0001	1.00
4.15	4	4	1.00	0.0001	1.00
4.16	4	4	1.00	0.0001	1.00
4.17	4	4	1.00	0.0001	1.00
4.18	4	4	1.00	0.0001	1.00
4.19	4	4	1.00	0.0001	1.00
4.20	4	4	1.00	0.0001	1.00
Mean	**3.95**	**3.95**	**0.99**	**0.0002**	**0.99**
				SD	**0.06**

3.6.18 AH's five-note chords

With respect to the five-note chords, AH makes additions to chords 5.8, 5.11, 5.12, 5.16, 5.18 and 5.19 and omissions to 5.3, 5.5, 5.6, 5.9, 5.10, 5.11, 5.12, 5.14, 5.15, 5.16, 5.18 and 5.19.

In chord 5.8, AH doubles the C in the 4th octave of the stimulus by playing it in the 5th octave; and in chord 5.9 AH adds a 9th (C5) and omits the 5th and the 7th (F and A♭).

In terms of omissions, AH does not play the inner notes in chords 5.3, 5.5, 5.6, 5.9, 5.10 and 5.15. In two chords, 5.14 and 5.15, AH omits the top note; however, her omission of the 5th octave D (top note) in chord 5.14 is played in the 4th octave of the chord. In this group of chords AH does not omit any bottom notes. Furthermore, the omissions made do not change the tonal nature of any of the chords.

Table 3.27 AH's chordal disaggregation data for five-note chords, with P and Z scores given (assuming #U=25).

5 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
5.1	5	5	1.00	0.0000	1.00
5.2	5	5	1.00	0.0000	1.00
5.3	4	4	0.80	0.0004	0.80
5.4	5	5	1.00	0.0000	1.00
5.5	4	4	0.80	0.0004	0.80
5.6	4	4	0.80	0.0004	0.80
5.7	5	5	1.00	0.0000	1.00
5.8	6	5	1.00	0.0001	1.00
5.9	4	3	0.60	0.0158	0.59
5.10	4	4	0.80	0.0004	0.80
5.11	5	4	0.80	0.0019	0.80
5.12	5	4	0.80	0.0019	0.80
5.13	5	5	1.00	0.0000	1.00
5.14	4	4	0.80	0.0004	0.80
5.15	3	3	0.60	0.0043	0.60
5.16	5	4	0.80	0.0019	0.80
5.17	5	5	1.00	0.0000	1.00
5.18	5	4	0.80	0.0019	0.80
5.19	5	4	0.80	0.0019	0.80
5.20	5	5	1.00	0.0019	1.00
Mean	**4.65**	**4.30**	**0.86**	**0.0017**	**0.86**
				SD	**0.13**

3.6.19 AH's six-note chords

With respect to the six-note chords, AH makes additions to chords 6.2, 6.4 and 6.5 and omissions to 6.2, 6.4, 6.5, 6.8, 6.9, 6.10, 6.11, 6.14, 6.17, 6.19 and 6.20. On two out of three occasions, AH's additions are repetitions of notes already present in the chord at different octaves (i.e. 6.4 and 6.5). Conversely, in 6.2 she adds B3 (the 9th) without playing G3 (the 7th). With regard to omissions, on three occasions (chords 6.9, 6.11 and 6.20) AH omits the pitch that is present in the stimulus twice at different octaves, playing it just once. On two occasions AH plays one of these pitches at the higher octave and another time at the lower octave. Other omissions (found in chords 6.8, 6.10, 6.11, 6.14, 6.17, 6,19 and 6.20) are made in the inner notes of the chord and do not change the harmonic structure.

Table 3.28 AH's chordal disaggregation data for six-note chords, with P and Z scores given (assuming #U=25).

6 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
6.1	6	6	1.00	0.0000	1.00
6.2	6	5	0.83	0.0006	0.83
6.3	6	6	1.00	0.0000	1.00
6.4	6	5	0.83	0.0006	0.83
6.5	6	5	0.83	0.0006	0.83
6.6	6	6	1.00	0.0000	1.00
6.7	6	6	1.00	0.0000	1.00
6.8	5	5	0.83	0.0001	0.83
6.9	5	5	0.83	0.0001	0.83
6.10	5	4	0.67	0.0054	0.66
6.11	4	4	0.67	0.0012	0.67
6.12	6	6	1.00	0.0000	1.00
6.13	6	6	1.00	0.0000	1.00
6.14	4	4	0.67	0.0012	0.67
6.15	6	6	1.00	0.0000	1.00
6.16	6	6	1.00	0.0000	1.00
6.17	5	5	0.83	0.0001	0.83
6.18	6	6	1.00	0.0000	1.00
6.19	5	4	0.67	0.0054	0.66
6.20	4	4	0.67	0.0012	0.67
Mean	**5.45**	**5.20**	**0.87**	**0.0008**	**0.87**
				SD	**0.14**

3.6.20 AH's seven-note chords

With respect to seven-note chords AH makes additions to the following: 7.1, 7.2, 7.3, 7.4, 7.13, 7.17 and 7.19 and omissions to 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.9, 7.10, 7.11, 7.12, 7.13, 7.14, 7.15, 7.17, 7.18, 7.19 and 7.20. AH transforms four of the chords through her additions and omissions (7.2, 7.5, 7.12 and 7.17). This means she either transposes the chords (internal on intervals) or she was transforming from minor to major by omitting or adding new notes.

The additions made in chords 7.1, 7.2, 7.3 and 7.19 are notes already present in the stimulus at different octaves. In chord 7.13, AH adds a 9^{th}. Chord 7.17 is transformed from a chord of F7 with an added (sharpened) 4^{th} (i.e., B) to one of D flat with a similarly sharpened 4^{th} (that is, G). This is the first time AH appears to be overwhelmed by the task (or perhaps has a failure of attention) and resorts to 'relative pitch' (RP) to produce a response. It is noteworthy that AH also makes an error here in the bass line (in chord 6.9, the only previous occasion when the bass line was incorrect, the pitch omitted was present elsewhere in the chord).

With regard to omissions, in most cases AH does not change the nature of the chord. However, a change can be seen in AH's interpretation of chord 7.2. AH maintains the same intervallic structure of the inner parts of this chord/the whole tone scale, but transposes the notes by a semitone. This chord is not analysed as an addition and/or omission but as a *transformation*. The initial chord that AH really struggles with is the first cluster, chord 7.2. AH also has difficulty with and did not recognise the other clusters presented (chords 7.9 and 7.12).

The following describes what occurred chord by chord. In chord 7.1 there are omissions and additions – but these do not change the harmonic nature of the chord. Chord 7.2 is the first example of a transformation as the whole tone scale is transposed. In chord 7.3 AH makes one omission and one addition. AH's response in chord 7.4 is very similar to that of chord 7.3 – additions of a 9^{th} (A) are made to the G7 chord. In chord 7.5 the stimulus presented is a diminished 7th chord of minor 3rds. AH hears the diminished 7th and splits the chord into two halves: one half is the original diminished 7th with some omissions, the other half is also a diminished 7th chord but transposed (the original is B, D, F, and the transposed version is C, E♭, F#). AH uses the same strategy that she did with chord 7.2, in which the whole tone scale was transposed. In both cases, she appears to use a combination of AP and relative pitch ('RP') as in her response some notes are copied exactly and some intervals are maintained (but not the notes themselves).

AH makes omissions to chords 7.6 and 7.7. Her responses in chords 7.8 to chords 7.11 are largely correct. In chord 7.12 the stimulus presented is a combination of F major in the left hand and E major in the right hand. AH seems to hear this as the chord G13th. She imposes a structure on the chord by combining the two implied tonal centres (F, E) into one harmony, G13th. The 4th interval of chord 7.12 is raised by a semitone, substituting C# instead of C. AH's knowledge of tonal structure helps to 'fill in' the inner notes of the chord where her AP was failing. For chord 7.13 (F major) AH adds a 9th and omits the 6th. AH adds a 7th to chord 7.14, a D minor 9th chord.

Omissions are made in chords 7.15 and 7.16. AH transposes and transforms chord 7.17. She hears the augmented 4th between the B and the F that gives this chord its characteristic sound. However, for the first time AH misses the bass note and plays D♭ instead of C, transforming the augmented 4th to a G. Chords 7.18, 7.19 and 7.20 contain a 13th and AH responds to all of these correctly.

It seems that, when responding, AH sometimes uses her conceptual understanding, her explicit rather than implicit knowledge, her intellect rather than intuition. This is evident when she plays the whole tone scale. That is, AH uses a different strategy from that of the savants: she uses a conceptual understanding of musical structure to which savants have no or limited access.

For example if you ask DP, a savant, the name of any chord beyond simple major and minor triads, he responds by saying 'diminish of diminished' (personal communication, Ockelford, 2013). This indicates that some savants may not have the theoretical knowledge or language to help them in their perceptual understanding of harmonic structure. Therefore, this implies that their results on the disaggregation of chords are based purely on perceptual ability. To conclude, non-savant musicians sometimes use their knowledge of harmonic structure to compensate for their perceptual limitations, whilst savants rely solely on their perceptual abilities.

Table 3.29 AH's chordal disaggregation data for seven-note chords, with P and Z scores given (assuming #U=25).

7 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
7.1	7	5	0.71	0.0051	0.71
7.2	7	3	0.43	0.2159	0.34
7.3	7	6	0.86	0.0000	0.86
7.4	7	6	0.86	0.0000	0.86
7.5	6	3	0.43	0.1549	0.36
7.6	5	4	0.57	0.0119	0.56
7.7	6	6	0.86	0.0000	0.86
7.8	7	7	1.00	0.0000	1.00
7.9	6	4	0.57	0.0398	0.55
7.10	5	4	0.57	0.0119	0.56
7.11	6	4	0.57	0.0398	0.55
7.12	6	3	0.43	0.1549	0.36
7.13	7	5.5	0.79	0.0025	0.78
7.14	6	5	0.71	0.0022	0.71
7.15	6	6	0.86	0.0000	0.86
7.16	7	7	1.00	0.0000	1.00
7.17	7	3	0.43	0.2159	0.34
7.18	4	4	0.57	0.0028	0.57
7.19	7	5	0.71	0.0051	0.71
7.20	6	6	0.86	0.0000	0.86
Mean	**6.25**	**4.83**	**0.69**	**0.0431**	**0.67**
				SD	**0.22**

3.6.21 AH's eight-note chords

With regard to the eight-note chords AH makes additions to each of the following: 8.3, 8.5, 8.9, 8.11, 8.12, 8.16 and 8.19; and omissions to 8.1, 8.2, 8.3, 8.4, 8.6, 8.7, 8.8, 8.9, 8.10, 8.11, 8.12, 8.13, 8.14, 8.16, 8.17, 8.18 and 8.20. Transformations are made in some chords (8.3, 8.5, 8.7, 8.8, 8.13, 8.16, 8.19).

AH's ability to recognise and identify the pitches becomes weaker as the chord size increases. The additions made in chords 8.3, 8.5 and 8.16 modify the harmonic structure of the chord. Aside from these three chords AH's omissions rarely modify the structure of the chords presented. However, the omissions made in clusters (chords 8.13, 8.16, 8.19 and 8.20) do change the nature of the chord, i.e. from major to minor and vice versa.
Chord by chord, this is what occurs. The stimulus presented in chord 8.1 is made up of the whole tone scale, which is recognised and replicated by AH on this occasion. AH correctly hears chord 8.3 as a C7th, though the details in her response are incorrect. AH changes some chords from minor to major, by either adding a minor or major 9th. These responses could suggest that her perceptual system is becoming overloaded.

AH recognises chord 8.4 and plays it correctly. She plays chord 8.5, a cluster, as tone/semitone, tone/semitone. However, she plays a different combination of notes using a mixture of her AP and RP; for example she copies some of the notes and intervals throughout the chord. In chord 8.6 AH only makes a few omissions. Chord 8.7 is presented as a combination of two diminished 7^{ths}, which AH fails to recognise. She produces an irregular cluster that again seems to combine elements of AP and RP in her performance. Chord 8.8 is another cluster, comprising a diminished 7th with two chromatic additions (AH adds a G in her right hand and A$^{\flat}$ in the left hand). She responds with six correct notes, one omission and one error in the left hand.

AH's responses to chords 8.9, 8.10, 8.11 and 8.12 are all correct or largely correct. Chord 8.13 is a cluster-based on a diminished 7th chord with chromatic additions (the A and the E♭). AH hears the majority of the notes in this chord, however she changes its nature. She plays the overall structure correctly but her additions are incorrect. The additions of C♭ and E again suggest that she uses her conceptual knowledge, in this case of diminished 7th chords, when her AP ability breaks down.

In her response to chord 8.14, AH makes a few omissions, whilst her response to chord 8.15 is correct. Chord 8.16 comprises a perfect 4th and semitones. In order to recognise this chord, AH apparently applies a combination of AP and RP, which results in her playing certain notes correctly (including the bass note). However, other notes that she plays in response to this stimulus (chord 8.16) seem like guesswork. AH's knowledge of tonal structure would not have helped her here since the stimulus is atonal. AH recognises chords 8.17 and 8.18, in which she misses few notes. AH responds to a cluster chord, 8.19, based on tones and semitones by playing a cluster. However, within this response she appears to guess the inner notes of the chord's structure. Finally, in response to chord 8.20 AH makes additions and omissions.

Table 3.30 AH's chordal disaggregation data for eight-note chords, with P and Z scores given (assuming #U=25).

8 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
8.1	5	5	0.63	0.0011	0.62
8.2	6	6	0.75	0.0002	0.75
8.3	8	4	0.50	0.1540	0.42
8.4	7	6	0.75	0.0010	0.75
8.5	10	7	0.88	0.0017	0.87
8.6	6	5.5	0.69	0.0017	0.69
8.7	7	4	0.50	0.0990	0.45
8.8	7	5.5	0.69	0.0084	0.68
8.9	8	7	0.88	0.0001	0.87
8.10	7	7	0.88	0.0000	0.87
8.11	8	7	0.88	0.0001	0.87
8.12	8	6	0.75	0.0035	0.75
8.13	7	5	0.63	0.0158	0.62

8.14	6	3.5	0.44	0.1344	0.38
8.15	8	8	1.00	0.0000	1.00
8.16	8	4	0.50	0.1540	0.42
8.17	6	6	0.75	0.0002	0.75
8.18	5	5	0.63	0.0011	0.62
8.19	9	6	0.75	0.0093	0.74
8.20	7	5	0.63	0.0158	0.62
Mean	**7.15**	**5.63**	**0.70**	**0.0301**	**0.69**
				SD	**0.17**

3.6.22 AH's nine-note chords

AH makes additions to the following chords: 9.2, 9.3, 9.7, 9.11 and 9.15 and omissions in 9.1, 9.3, 9.5, 9.7, 9.8, 9.9, 9.10, 9.13, 9.14, 9.15, 9.16, 9.17, 9.18, 9.19, 9.20 as well as transpositions in 9.9.

The following occurs chord by chord. In response to chord 9.1, a cluster, AH plays a similar cluster with some internal errors. She substitutes an F♭ for the F natural and a D♭ for a D natural. In 9.2, AH plays another cluster with internal substitutions and errors. In the previous example (9.1), AH's use of AP is evident, whereas in 9.2, she appears to use a combination of AP and RP, since intervals are repeated at different levels (for example, the G major chord at the top of the cluster becomes C major in her response). This may occur because her AP ability is overwhelmed when hearing so many pitches at the same time. There also seems to be an element of filling in the gap between the top and the bottom notes by guessing the notes that lie in between. Within this example, no systematic transformations are heard.

AH's playing of chord 9.3 is largely correct (with some octave substitution). Chord 9.4 is a cluster, relatively easy to recognise, being the major scale of D starting on G. AH recognises this and plays it correctly. Chord 9.5 is a more complicated cluster to process: AH appears to be largely guessing in her response, which is inaccurate. Again she seems to be overwhelmed by the task, and her response sounds completely different from the stimulus. AH plays chord 9.6 perfectly. Chord 9.7 is another cluster, based on a tone-semitone pattern. AH substitutes the inner notes using a different pattern, but one that still uses tones and semitones. It seems as though she hears that the chord is made up of tones and semitones, however she does not hear in which order the notes are presented. It is possible that she is using her theoretical knowledge of music (gained as an advanced student at the Royal Academy of Music) and her sense of relative pitch. In chord 9.8 AH appears to adopt a similar strategy in her response.

Chord 9.9 can be defined as a cluster (it is a whole tone scale). AH appears to recognise this, but she transposes the cluster of notes by one semitone – a 'relative pitch' strategy. Interestingly, she hears and plays the bottom note correctly, even though it is not part of the whole tone scale she produced. It seems as though she is struggling to hear the notes, and she ends up using two different strategies that do not result in a correct response: the first is the AP strategy, in her hearing and playing of the bottom note, and the second is to hear the overall chordal structure.

Looking at AH's responses as a whole, it seems that AH is able to use her AP quite well with the smaller chords (4-5 notes). With the medium size chords (6-7 notes), she seems to use a mixture of AP and RP, because she has a high number of correct notes in absolute terms, but she also systematically transforms some of the other notes using relative pitch (that is transposition). With the largest chords (8-9 notes) it seems that her perceptual systems are often overwhelmed (particularly with the clusters) and she appears to resort to guesswork that results in errors.

This overwhelmed response is evident in AH's playing of chord 9.11, a cluster, which is a mixture of two whole tone scales. Although she plays one of the whole tone scales correctly within this cluster, there are a number of errors in her processing of the second, demonstrating a high rate of error. In her response to chord 9.12, a 9^{th} chord in second inversion, AH plays a cluster by filling in some of the intervening semitones – in other words she inserts notes that are each a semitone away from the stimulus note due to the close spacing of the notes within the chord. Perhaps AH was expecting a cluster because several of the previous stimuli presented had been.

AH nearly plays chord, 9.13, a whole tone scale, almost correctly. Her mistake is to insert a note, a semitone apart from two others in the scale. Again it appears as though AH's perceptual abilities are being overwhelmed by the task as a whole, since this chord is not considered to be a challenge for someone with AP. Chord 9.14 is a minor 9th with the root at the top, which AH simplifies in her response. 9.15 is another 9th chord and its close spacing makes it sound like a cluster, though it is not. Again AH seems to be overwhelmed in her response here, which has many errors, including the bass note, which is unusual for her. Chord 9.16 is also a 9th chord, which one would expect AH to respond to correctly, given her rate of success within the test. However, the introduction of a C#, a non-harmonic tone within the chord, creates the illusion of a cluster.

Reviewing the final nine-note chords: AH simplifies 9.17 in her response and adds non-harmonic tones to chord 9.18, another 9th chord. Chord 9.19 is a cluster, based on a major scale, which, interestingly, AH converts into a 9th chord (perhaps picking up on the previous 9th chords discussed above). Finally, chord 9.20 is also a 9th chord on B, which AH complicates by adding an unresolved chromatic note (F natural).

Table 3.31 AH's chordal disaggregation data for nine-note chords, with P and Z scores given (assuming #U=25).

9 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
9.1	8	6	0.67	0.0093	0.66
9.2	10	5.5	0.61	0.1082	0.54
9.3	9	8	0.89	0.0001	0.89
9.4	9	9	1.00	0.0000	1.00
9.5	6	1	0.11	0.2220	0.09
9.6	9	9	1.00	0.0000	1.00
9.7	9	6	0.67	0.0230	0.65
9.8	8	6	0.67	0.0093	0.66

9.9	8	1	0.11	0.0952	0.10
9.10	8	8	0.89	0.0000	0.89
9.11	11	6	0.67	0.0828	0.61
9.12	9	7	0.78	0.0021	0.78
9.13	8	6	0.67	0.0093	0.66
9.14	6	6	0.67	0.0005	0.67
9.15	10	4	0.44	0.3102	0.31
9.16	7	5	0.56	0.0315	0.54
9.17	6	5.5	0.61	0.0059	0.61
9.18	8	5	0.56	0.0652	0.52
9.19	8	6	0.67	0.0093	0.66
9.20	6	4	0.44	0.0854	0.41
Mean	**8.15**	**5.70**	**0.63**	**0.0535**	**0.61**
				SD	**0.25**

3.6.23 AH summary

When summarising AH's responses one notices that with the smaller chords AH occasionally changes the octaves; with the more complicated chords within this size group she hears and replicates the structure but sometimes transposes notes (that is, she copies intervals using RP). When responding to large chords it seems that AH's perceptual faculties are overwhelmed and that her playing consists, to a greater or lesser extent, of guesswork. The 9th chords in particular prove to be difficult for AH and her score is quite low in comparison to the scores obtained by the savants in the study. Table 3.32 and Figure 3.47 display the number of additions and omissions made by AH per each group of chords.

Table 3.32 The relative positions of the notes omitted by AH.

Chord size	**No. of notes**	**Top note**	**2nd down**	**3rd down**	**4th down**	**Middle note**	**4th up**	**3rd up**	**2nd up**	**Bottom note**	**Sums**
4	80	1	0	-	-	-	-	-		0	1
5	100	3	2	-	-	6	-	-	3	0	14
6	120	1	3	2	-	-	-	6	3	1	16
7	140	6	8	8	-	7	-	5	11	1	46
8	160	13	6	7	7	-	6	5	6	0	50
9	180	9	11	7	11	7	7	6	8	2	68
Sums	780	33	30	24	18	20	13	22	31	4	195
		Sum of lower half = 105					Sum of lower half = 70				

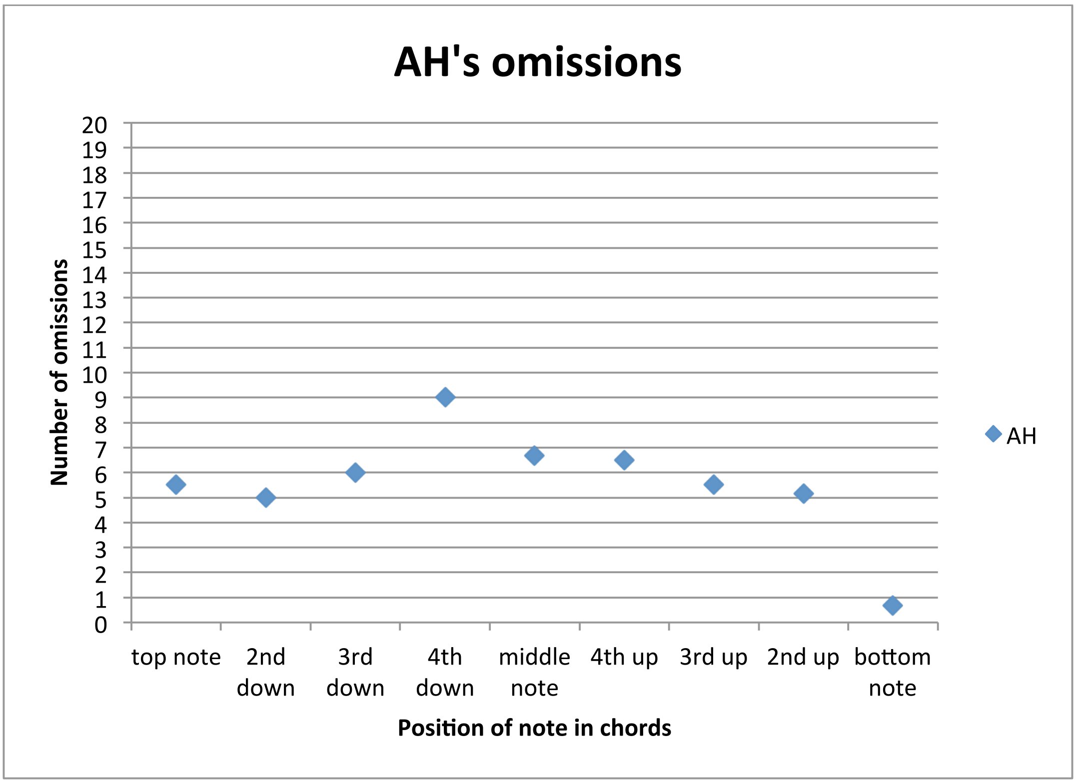


Fig. 3.47 AH’s average of omissions inside the chords.

The position of the additions and omissions correspond with results (Mazzeschi et al., 2011; Ockelford, 2012) showing that the most successful non-savants share a strategy with savants, who tend to listen to chords ‘from the bottom up’ (*cf.* 3.6.15). It seems that this strategy is very effective as it has enabled the non-savants within this study to be more successful in disaggregating chords. The bass note of chords often dictates their structure. Therefore, hearing and playing the bottom note correctly, indicates that the structure is more likely to have been recognised. Hence the responses are more likely to be correct.

3.6.24 CP’s capacity for disaggregating chords – results of testing

In CP’s case, the differences between R and Z scores are minor, since the probabilities of such high levels of accuracy occurring by chance are very small. However, where values of R are lower, the impact on Z is greater. Furthermore, as the size of the chord increases, CP’s responses show a general decline in accuracy (see Figure 3.48 and Table 3.33).

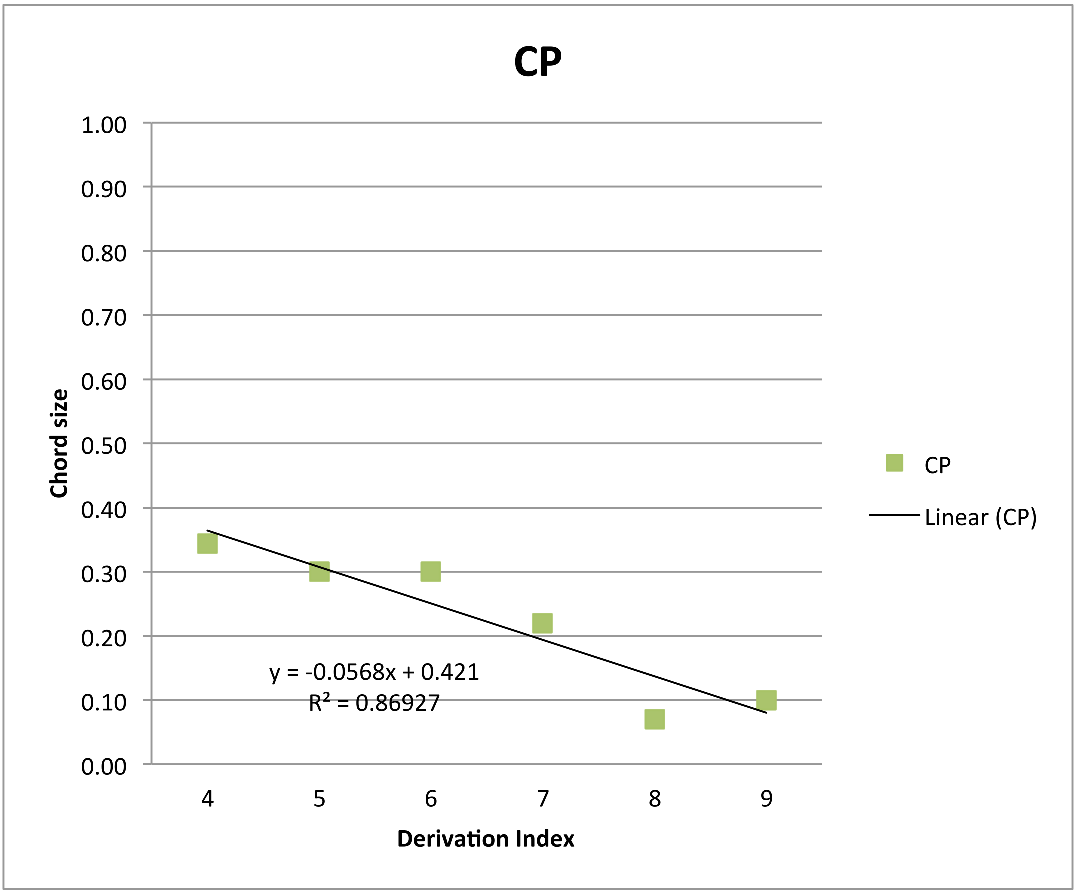


Fig. 3.48 CP's accuracy results.

Table 3.33 CP's weighted mean scores and standard deviations.

Size of the chord	Z	SD
4	0.34	0.22
5	0.30	0.25
6	0.30	0.20
7	0.22	0.19
8	0.07	0.09
9	0.10	0.09

Figures 3.49a and 3.49b show the stimuli followed by the responses performed by CP for 4 to 9 note chords. Tables 3.34 to 3.39 provide the detailed results of CP's performance for each set of chords. In CP's case, the differences between R and Z are considerable, since the probabilities, or notes being reproduced correctly by chance are considerable.

Fig. 3.49 (a) CP's responses to four-, five-, six- and seven-note chordal stimuli.

Fig. 3.49 (b) CP's responses to seven-, eight- and nine-note chordal stimuli.

3.6.25 CP's four-note chords

In response to all the 4 note chords, CP makes substantial omissions (from chords 4.1 to 4.20). The majority of her responses consist of only 3 notes and throughout the four-chord group 1/3 of the pitches she plays are correct. In 16 out of 20 cases CP's top note is correct, though on six occasions she plays in the wrong octave. One interpretation might be that she is using AP for the top note and RP to complete the chord. She may also be using this strategy in her response to chord 4.2, in which she plays a Gm 7th instead of a Dm 7th.

Table 3.34 CP's chordal disaggregation data for four-note chords, with P and Z scores given #U=25.

4 note chords					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
4.1	3	3	0.75	0.0017	0.75
4.2	3	1	0.25	0.3652	0.16
4.3	3	1.5	0.38	0.2100	0.30
4.4	3	0.5	0.13	0.4717	0.07
4.5	3	1.5	0.38	0.2100	0.30
4.6	3	1.5	0.38	0.2100	0.30
4.7	3	0	0.00	0.5782	0.00
4.8	3	2.5	0.63	0.0283	0.61
4.9	3	2	0.50	0.0548	0.47
4.10	3	1.5	0.38	0.2100	0.30
4.11	3	2	0.50	0.0548	0.47
4.12	3	3	0.75	0.0017	0.75
4.13	3	2	0.50	0.0548	0.47
4.14	3	1	0.25	0.3652	0.16
4.15	3	2	0.50	0.0548	0.47
4.16	3	2	0.50	0.0548	0.47
4.17	3	1.5	0.38	0.2100	0.30
4.18	3	0.5	0.13	0.4717	0.07
4.19	0	0	0.00	1.0000	0.00
4.20	3	2	0.50	0.0548	0.47
Mean	**2.85**	**1.55**	**0.39**	**0.2331**	**0.34**
				SD	**0.22**

3.6.26 CP's five-note chords

CP makes many omissions in the 5 note chords (from 5.1 to 5.20). She plays either 3 or 4 notes in response, omits several notes, or does not play the chord at all (e.g. 5.20). In this group of chords CP plays the correct top note eight times out of twenty; resulting in a higher rate of error for the top notes than the inner notes. It seems that AP and RP are both employed in order to replicate chords as far as possible. Nonetheless, 30% of her answers are correct.

Table 3.35 CP's chordal disaggregation data for five-note chords, with P and Z scores given #U=25.

5 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
5.1	3	0.5	0.10	0.4543	0.05
5.2	4	0.5	0.10	0.4168	0.06
5.3	0	0	0.00	1.0000	0.00
5.4	3	1	0.20	0.4130	0.12
5.5	3	2	0.40	0.0870	0.37
5.6	3	3	0.60	0.0043	0.60
5.7	0	0	0.00	1.0000	0.00
5.8	4	3	0.60	0.0158	0.59
5.9	4	1.5	0.30	0.3004	0.21
5.10	4	3	0.60	0.0158	0.59
5.11	4	3.5	0.70	0.0081	0.69
5.12	4	3	0.60	0.0158	0.59
5.13	4	3	0.60	0.0158	0.59
5.14	4	3.5	0.70	0.0081	0.69
5.15	4	1.5	0.30	0.3004	0.21
5.16	4	1	0.20	0.4506	0.11
5.17	4	1	0.20	0.4506	0.11
5.18	4	1	0.20	0.4506	0.11
5.19	4	2	0.40	0.1502	0.34
5.20	0	0	0.00	1.0000	0.00
Mean	**3.2**	**1.7**	**0.34**	**0.3279**	**0.30**
				SD	**0.25**

3.6.27 CP's six-note chords

In the six-note chords CP omits around half of the notes in total; in two cases, she provides no response at all. CP responds with the correct top note 13 times out of 20, compared to a higher rate of error for the inner and bottom notes. CP's responses indicate that the task is difficult for her and there is a sense that she is overwhelmed. She appears to guess some of her responses, and does not use a combination of her (limited) AP and RP, as some of the other participants (AH) do.

Table 3.36 CP's chordal disaggregation data for six-note chords, with P and Z scores given #U=25.

6 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
6.1	1	1	0.17	0.2400	0.13
6.2	5	0.5	0.08	0.3283	0.06
6.3	4	2	0.33	0.2028	0.27
6.4	4	1.5	0.25	0.3312	0.17
6.5	4	1	0.17	0.4596	0.09
6.6	0	0	0.00	1.0000	0.00
6.7	4	3.5	0.58	0.0156	0.57
6.8	4	3	0.50	0.0300	0.48
6.9	3	2	0.33	0.1239	0.29
6.10	3	2	0.33	0.1239	0.29
6.11	5	3.5	0.58	0.0349	0.56
6.12	5	2	0.33	0.2736	0.24
6.13	4	2.5	0.42	0.1164	0.37
6.14	4	3	0.50	0.0300	0.48
6.15	0	0	0.00	1.0000	0.00
6.16	4	3	0.50	0.0300	0.48
6.17	4	3	0.50	0.0300	0.48
6.18	0	0	0.00	1.0000	0.00
6.19	4	3	0.50	0.0300	0.48
6.20	4	3.5	0.58	0.0156	0.57
Mean	**3.3**	**2**	**0.33**	**0.2708**	**0.30**
				SD	**0.20**

3.6.28 CP's seven-note chords

CP makes omissions in all chords (from 7.1 to 7.20) within the 7-note group. CP's responses, in which she plays fewer notes per chord than she does for the six-note chords, again suggest that the experiment is very challenging for her.

Table 3.37 CP's chordal disaggregation data for seven-note chords, with P and Z scores given #U=25.

7 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
7.1	2	1.5	0.21	0.2450	0.16
7.2	3	1	0.14	0.4657	0.08
7.3	2	0.5	0.07	0.4650	0.04
7.4	3	2	0.29	0.1643	0.24
7.5	0	0	0.00	1.0000	0.00
7.6	3	2	0.29	0.1643	0.24
7.7	4	4	0.57	0.0028	0.57
7.8	4	2.5	0.36	0.1519	0.30
7.9	4	2.5	0.36	0.1519	0.30
7.10	4	1.5	0.21	0.3528	0.14
7.11	0	0	0.00	1.0000	0.00
7.12	5	2.5	0.36	0.2117	0.28
7.13	4	3.5	0.50	0.0263	0.49
7.14	4	3	0.43	0.0498	0.41
7.15	4	4	0.57	0.0028	0.57
7.16	0	0	0.00	1.0000	0.00
7.17	2	1	0.14	0.4200	0.08
7.18	5	3	0.43	0.1008	0.39
7.19	1	1	0.14	0.2800	0.10
7.20	2	0	0.00	0.5100	0.00
Mean	**2.8**	**1.775**	**0.25**	**0.3382**	**0.22**
				SD	**0.19**

3.6.29 CP's eight-note chords

In response to the eight-note chords CP makes omissions throughout the whole section (from chords 8.1 to 8.20). Her tendency to play only one note (from 8.1 to 8.9 and in 8.14 and 8.17) demonstrates that she struggles with the task. Neither the top nor the bottom notes are replicated (which most other participants found the easiest to hear).

CP's responses indicate that she finds hearing and replicating the eight-note chords a demanding assignment, no doubt due to the interference effect of so many notes; she is completely overwhelmed. Her score for the eight-note chords is the lowest among all chord groups thus far.

Table 3.38 CP's chordal disaggregation data for eight-note chords, with P and Z scores given #U=25.

8 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
8.1	1	0	0.00	0.6800	0.00
8.2	1	1	0.13	0.3200	0.09
8.3	1	0	0.00	0.6800	0.00
8.4	1	0.5	0.06	0.5000	0.03
8.5	1	1	0.13	0.3200	0.09
8.6	1	0	0.00	0.6800	0.00
8.7	1	1	0.13	0.3200	0.09
8.8	1	0.5	0.06	0.5000	0.03
8.9	1	0	0.00	0.6800	0.00
8.10	4	2	0.25	0.3010	0.17
8.11	2	2	0.25	0.0933	0.23
8.12	3	1.5	0.19	0.3400	0.12
8.13	4	1.5	0.19	0.3655	0.12
8.14	1	0	0.00	1.0000	0.00
8.15	4	3	0.38	0.0753	0.35
8.16	4	1.5	0.19	0.3655	0.12
8.17	1	0.5	0.06	0.5000	0.03
8.18	0	0	0.00	1.0000	0.00
8.19	0	0	0.00	1.0000	0.00
8.20	0	0	0.00	1.0000	0.00
Mean	**1.6**	**0.8**	**0.1**	**0.5360**	**0.07**
				SD	**0.09**

3.6.30 CP's nine-note chords

CP attempts only one note per chord on average for the nine-note chords. These individual notes are largely correct. CP performs better in this group than the eight-note chords. One hypothesis could be that she is relieved the task is about to end – and so renews her focus. The lower rate of error here might also be in part due to the fact that the probability of getting a note correct at this stage is greater than 1 in 3.

Table 3.39 CP's chordal disaggregation data for nine-note chords, with P and Z scores given #U=25.

9 note chord					
Chord number	**#R**	**#C**	**R**	**P**	**Z**
9.1	0	0	0.00	1.0000	0.00
9.2	1	1	0.11	0.3600	0.07
9.3	1	1	0.11	0.3600	0.07
9.4	2	2	0.22	0.1200	0.20
9.5	1	1	0.11	0.3600	0.07
9.6	4	4	0.44	0.0100	0.44
9.7	1	1	0.11	0.3600	0.07
9.8	1	1	0.11	0.3600	0.07
9.9	1	1	0.11	0.3600	0.07
9.10	1	1	0.11	0.3600	0.07
9.11	2	1.5	0.17	0.3000	0.12
9.12	1	1	0.11	0.3600	0.07
9.13	1	1	0.11	0.3600	0.07
9.14	1	1	0.11	0.3600	0.07
9.15	1	1	0.11	0.3600	0.07
9.16	1	1	0.11	0.3600	0.07
9.17	2	2	0.22	0.1200	0.20
9.18	1	0.5	0.06	0.5000	0.03
9.19	1	1	0.11	0.3600	0.07
9.20	1	1	0.11	0.3600	0.07
Mean	**1.25**	**1.2**	**0.13**	**0.3545**	**0.10**
				SD	**0.09**

3.6.31 CP summary

In summary, CP tends to omit notes. She plays only 300 notes in total (compared with 780 present in the stimuli) – and the number of notes played tends to diminish as the chord size increases, suggesting that the task was becoming even more challenging for her. On only three occasions out of 120 CP plays a note higher than the top note of the stimulus, whereas 27 times out of 120 she plays a note lower than the bass note. This suggests that she tends to focus on the higher notes, which presumably she finds easier to process than those lower down.

Furthermore, CP makes significant errors by positioning notes in the wrong octave 56 times (out of a total of 204 correct responses – around 27%). While pitch height confusion is recognised in AP judgements (since the ‘chroma’ remains the same), this appears nonetheless to be a surprisingly high proportion.

With the smaller sized chords, it appears that CP hears one note using her AP and then ‘calculates’ the other notes utilising her RP (see chord 4.2). Towards the end, with the larger chords, CP seems to use her AP when hearing and replicating one note (usually at or near the top of the chord). She apparently becomes overwhelmed and therefore does not use RP to calculate other notes as she did previously.

Overall CP’s performance gives the impression that the task is very demanding for her. It is important to remember that, although she performs poorly in comparison to the savants and most of the non-savants, she still achieves a score that is above chance, and well beyond the capability of most Western musicians (the majority of whom do not have AP). Table 3.40 and Figure 3.50 display the number of omissions made by CP per each group of chords.

Table 3.40 The relative positions of the notes omitted by CP.

Chord size	No. of notes	Top note	2nd down	3rd down	4th down	Middle note	4th up	3rd up	2nd up	Bottom note	Sums
4	80	10	19	-	-	-	-	-	16	11	56
5	100	14	12	-	-	13	-	-	15	17	71
6	120	11	14	16	-	-	-	15	14	15	85
7	140	18	17	18	-	17	-	15	13	14	112
8	160	20	20	19	19	-	15	17	19	19	148
9	180	18	17	15	16	18	16	19	19	19	157
Sums	780	91	99	68	35	48	31	66	96	95	629
		Sum upper half = 293					Sum of lower half = 288				

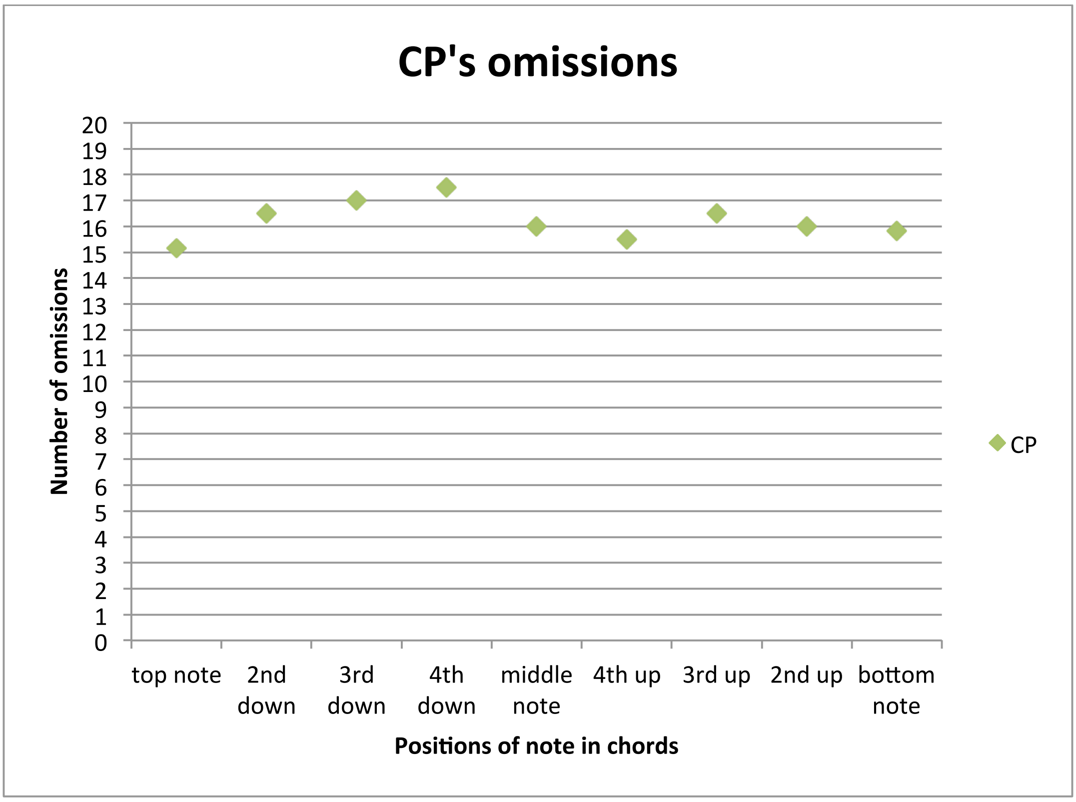


Fig. 3.50 CP's number of omissions in the chords.

Concerning the location of the omissions, CP tends to listen to the chord from the 'top down'; this strategy appears to be less effective than the 'bottom up' approach. This 'top down' method is also adopted by the other less successful non-savant comparisons within the study.

3.7 Discussion of the cases

Previously, Ockelford (2008; 2012) undertook work using chordal analysis to compare the experimental data of two savants and one non-savant. The current research extends the analysis to include the new factor of chord complexity (in addition to the size of the chords, tonal/cluster, and the top, inner and bottom notes). It also involves four more savants (NS, LH, NW, GN) and sixteen non-savant comparisons (initials of the 16). An in depth analysis has focussed on three subjects: the savant NS, the highest performing non-savant comparison, AH, and one of the lower performing non-savants, CP. When reviewing the overall results, the highest scoring non-savant comparison (AH) uses similar strategies to the savants, whereas the lowest scoring non-savant comparison uses different strategies altogether. The detailed analysis of each participant's results partially confirms this assumption. In fact, (AH) uses the same 'bottom up' approach when listening to the chords, employed by the savants in the study. However, AH appears to be more diligent in attempting to replicate every note correctly, using AP and RP, rather than conveying a general sense of the harmony that she hears. In contrast, the savant (NS) tends to produce responses that are more musically coherent, sometimes at the expense of the accurate reproduction of the stimulus.

With regard to CP's results, there is a sense that she is overwhelmed by the tasks in the experiment. She draws on both her AP and RP, although at times she responds by playing only one note from the chords presented. This suggests that she is trying to achieve at least a partially correct response (of one note) when listening to the larger sized chords. Table 3.41 and Figure 3.51 display the results of AH, NS and CP together.

Table 3.41 Weighted mean scores of AH, NS and CP.

Chord size	AH	NS	CP
4	0.99	0.91	0.34
5	0.86	0.90	0.30
6	0.87	0.92	0.30
7	0.67	0.85	0.22
8	0.69	0.76	0.07
9	0.61	0.68	0.10

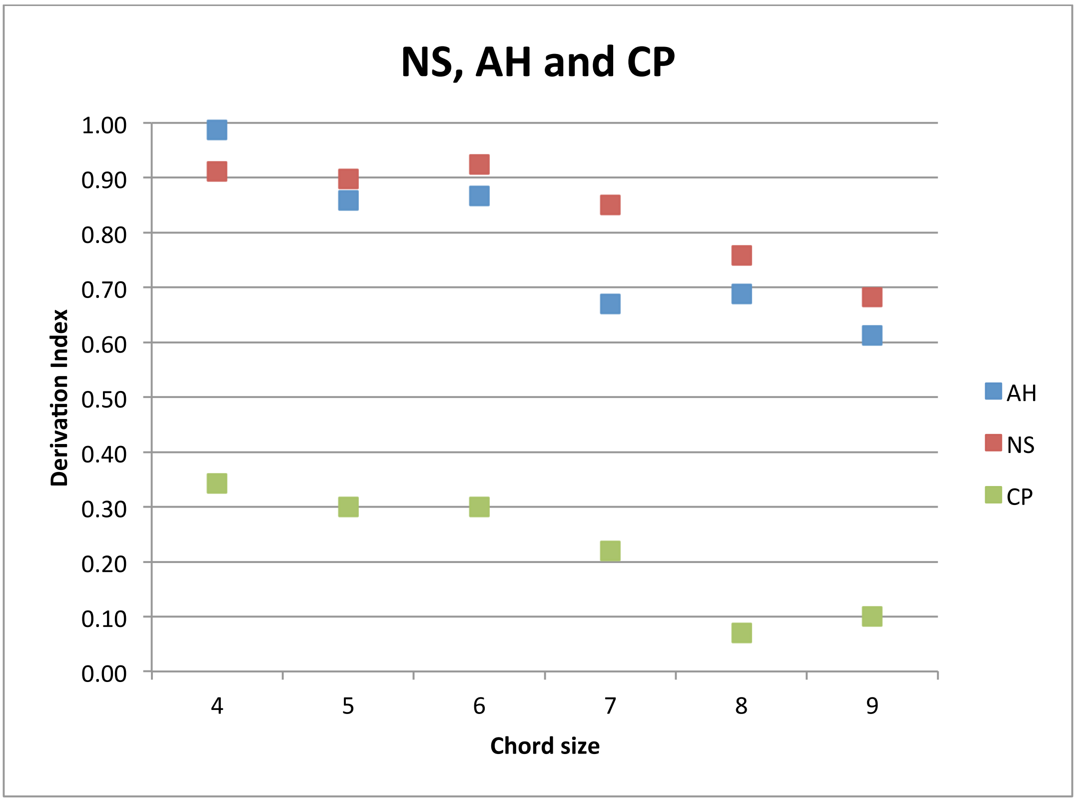


Fig. 3.51 Accuracy results for AH, NS and CP.

Concerning the omissions of these three participants, one can see that fewer omissions are made by NS, in the majority of cases in the inner and top notes (see Table 3.42 and Figure 3.52). A similar pattern can be observed in the non-savant comparison AH, who, again, makes fewer omissions of the bottom note, and more omissions from the inner parts of the chord. CP omits notes throughout the stimuli (top, inner and bottom notes).

Table 3.42 Average of omissions inside the chords for NS, AH and CP.

Participants	**Top note**	**2nd down**	**3rd down**	**4th down**	**Middle note**	**4th up**	**3rd up**	**2nd up**	**Bottom note**
AH	5.5	5.0	6.0	9.0	6.7	6.5	5.5	5.2	0.7
NS	3.8	3.2	4.0	7.0	6.3	5.5	4.8	2.0	1.0
CP	15.2	16.5	17.0	17.5	16.0	15.5	16.5	16.0	15.8

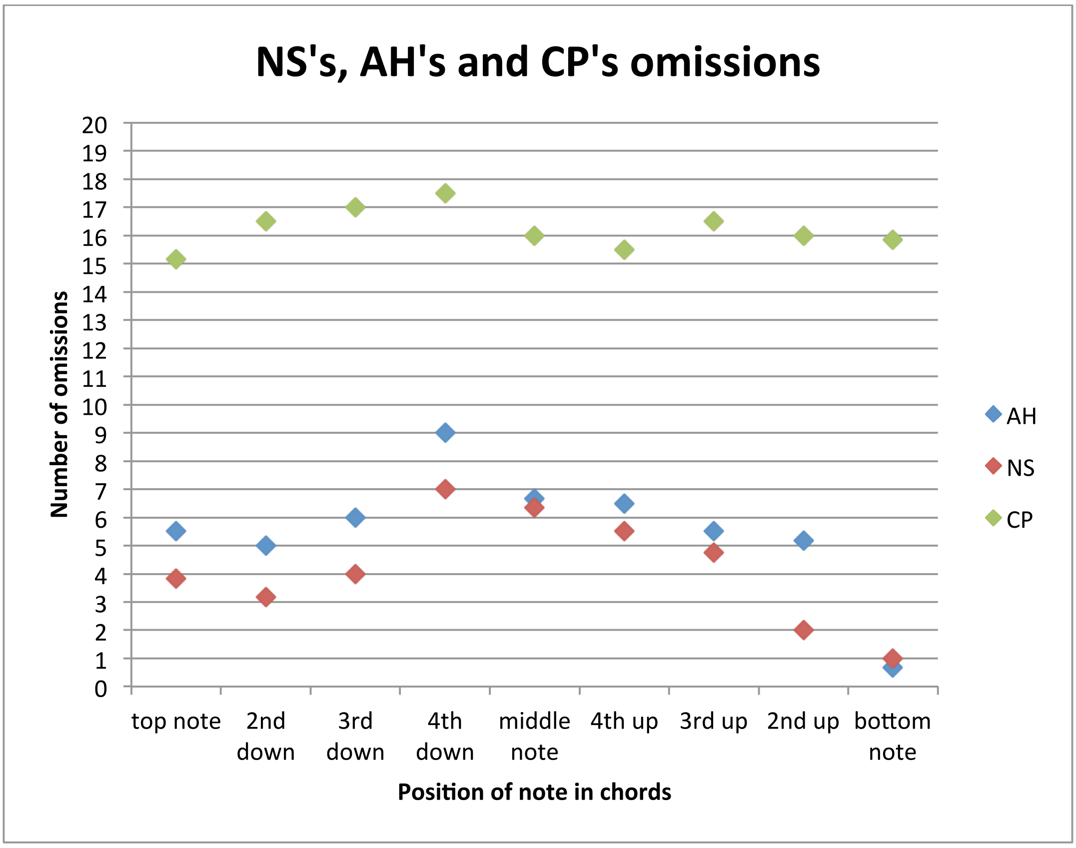


Fig. 3.52 Average of omissions inside the chords for NS, AH and CP.

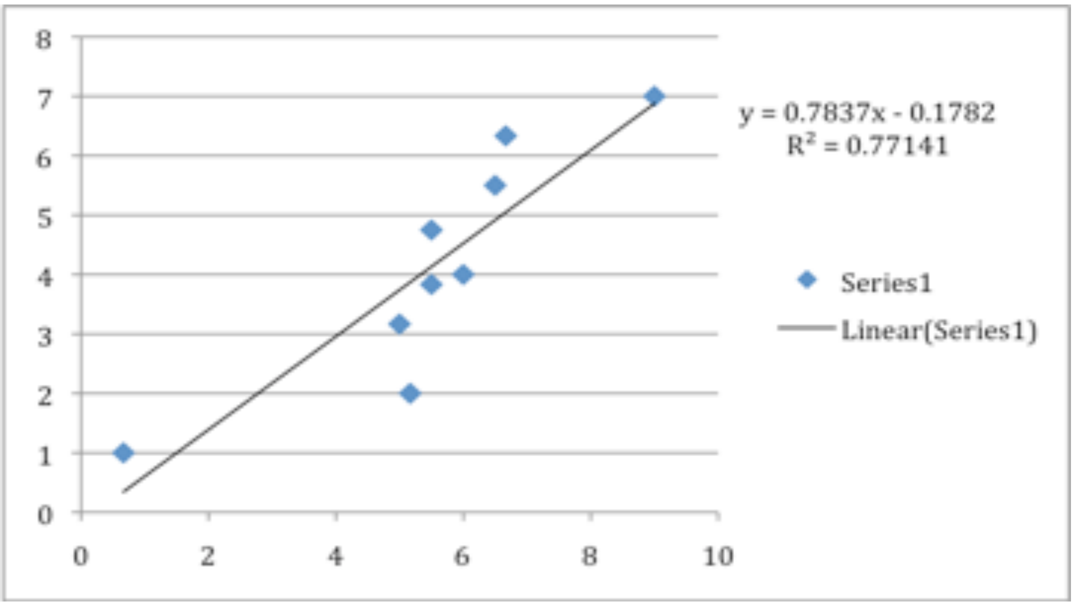


Fig. 3.53 Correlation between NS and AH.

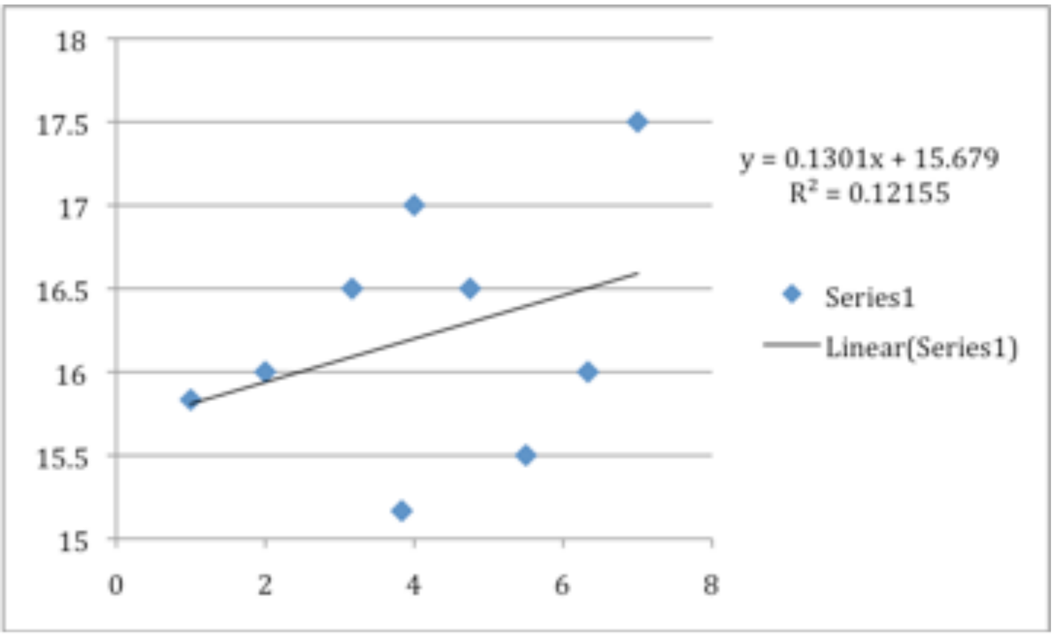


Fig. 3.54 Correlation between NS and CP.

Looking at the graphical representation of omissions above, in Figures 3.53 and 3.54 the *x-axis* represents the position of the omissions in the chord (top note, 2nd down, 3rd down, 4th down, middle note, 4th up, 3rd up, 2nd up and bottom note). The *y-axis* represents the correlation of omissions between NS and AH (in Figure 3.53) and the correlation of omissions between NS and CP (in Figure 3.54). Figures 3.53 show a high correlation between the patterns of omissions made by NS and AH, suggesting that they process the pitches in the chords in a similar way, while Figure 3.54 shows a low correlation between NS and CP. This suggests that NS and CP adopt different listening strategies.

The case studies show that there are important differences between AH and NS (notwithstanding the similar 'bottom up' listening strategy). For example, when AH finds the large chords difficult, she appears to employ her RP and uses what may be termed 'explicit' musical knowledge. She creates material that makes musical sense but that does not conform to the absolute pitches in the chords (rather, their pattern of intervals) – for example, see chord 9.9, with its alternating pattern of tones and semitones. NS, in contrast, seems only to use

AP, since the errors he makes do not involve imitating intervals when he tries to approximate to chords that make ‘musical sense’ (e.g. chords 9.7 and 9.8).

3.8 Conclusion

The results of the ‘listen and play’ chordal experiment have been analysed by examining various musical aspects of the chords such as: size, complexity, tonal content, and note position (top, inner or bottom).

These findings demonstrate that, taken as whole, savants within the study perform better than non-savants, although there are some overlaps across all chord sizes. With regard to chord complexity, savants outperform non-savant comparisons as a whole across all four levels, although, as the chords become more complex the accuracy of the scores decreases in all participants. This suggests a similarity in the way that savants and non-savants perceive chords, since they are both affected by structural complexity. In other words, it is not just a question of AP operating in isolation: chordal structure (entailing relative pitch judgements) has an impact too.

A similar situation exists in relation to the tonal (or lack of tonal) implications in the chords. The savants consistently outperform the non-savants as a whole, but both groups are affected by tonality (or a lack of it). That is, the level of familiarity with Western probabilistic pitch structures affect their achieved scores. Again, this suggests that there are similarities in the way that savants and some non-savants process chords.

Detailed analysis of the chords illustrates that for top, inner and bottom notes, savants and the least successful non-savants achieved ‘opposite’ scores. This implies that they process the notes differently (according to their relative position) and apply different strategies. Savants and the highest scoring non-savant comparison achieve better results in the accuracy of the bottom note, which usually functions as the root (bass) of the chordal structure. However, non-savants are consistently more accurate in respect of the top notes rather than the bottom notes, for which they proportionately make more errors. Hence it could be that the non-savant comparisons grasp only the contour, (i.e. the outer structure of the chord), whereas the savants perceive the chord's constituent material.

To conclude, the top, inner and bottom note analysis indicates that all savants within the study and five non-savants (with one borderline case) – around a third of the comparison group – achieve greater accuracy in relation to 'bottom' (bass) notes, whereas the remaining non-savants are more consistent with the top notes. This could indicate that the savants and some of the non-savants are adopting a similar listening strategy that is more interrogative of harmonic structure.

With regard to the in depth analysis of NS (savant), AH (non-savant comparison) and CP (non-savant comparison), individually, NS tends to produce responses that 'make sense' musically (sometimes apparently at the expense of accurate reproduction). It seems that AH is looking to reproduce the sound that she hears with the maximum amount of similarity as possible, even when this means producing chords that do not 'make sense'. The common strategy – apparently listening from the bottom up – is a very successful one, which enables both of these participants to achieve good results in the experiment. On the other hand, when examining CP's results in detail, it is determined that she seeks to identify the top note of the chord (instead of the bass), and sometimes this is the only note that she is able to respond to quickly enough.

Furthermore, CP uses her absolute pitch for the small sized chords to recognise and replicate the top note and tries to complete the inner structure using relative pitch. As the chords increases in size CP's accuracy in hearing the top note declines and subsequently she is no longer able to hear the inner structure. Overall, her performance suggests that the task is above her abilities, which resulted in very low scores. However, it is worth mentioning that the task is very difficult in itself and she may well have excellent pitch perception, which possibly is superior to most musicians.

CHAPTER 4: MUSICAL MEMORY TEST: *CLASSICAL TURN*

4.1 Introduction

The research described in this chapter investigates the nature of DP's musical memory. This extends Ockelford's research (2012), in which DP attempted to learn and recall an especially-designed piece of music called *Chromatic Blues* over a period of four years by listening to the entire piece and trying to play it back as a whole. Here, a structurally equivalent new composition called *Classical Turn* is used, which DP was asked to learn and recall bar by bar, to the best of his ability. Through psychomusicological analysis, the strategies he adopted are identified, and these are discussed.

4.2 Context

In the 2005 'REMUS' Project ('Researching Exceptional MUsical Skill') (*cf.* 2.5.1), Ockelford proposed a series of studies that would explore the ways in which DP characteristically learns music.

These were:

1. 'Listen and play' (Ockelford, 2005; 2008; 2012)
2. 'A bit at a time' (this study)
3. 'Play along' (Grundy and Ockelford, 2014)
4. 'Just listen'

These reflect the ways in which DP normally learns pieces, and are important in terms of ecological validity – a crucial aspect of research with savants, and essential in seeking to gather representative and meaningful data.

The aims of these studies (Ockelford, 2012) are to:

- record in detail DP's efforts at learning and recalling pieces presented in different ways (and following different protocols of reproduction)

- analyse the collected data and to use the results to build a paradigm of how DP learns and reproduces pieces of music
- compare how different protocols affect the speed and accuracy of learning and reproduction, taking into account interference and retention
- evaluate each approach in a pedagogical context (allowing suggestions to be made regarding future strategies for teaching DP and other savants, that take into account their preferred learning styles)
- consider what the findings may tell us, if anything, about musical learning and recall in general terms
- propose future directions of research based on the findings

Study 1 (‘Listen and play’) uses a novel piece entitled *Chromatic Blues*, and is reported extensively in Ockelford (2005; 2008; 2012). The procedure involves DP attempting to learn and recall a piece of music by listening to it and trying to play it all the way through. The research reported here comprises Study 2 (‘A bit at a time’) which entails DP learning a novel piece entitled *Classical Turn* bar by bar. For comparison purposes, *Classical Turn* matches *Chromatic Blues* for the number and density of events and structure (*cf.* section 4.4.1 below).

4.3 Hypothesis and aims

In her article on the development of memorisation strategies in musicians, Hallam (1997) sets out how methods change with developing expertise. She notices individual differences, such as the use of visual, kinaesthetic and aural strategies, which at times are used simultaneously. Hallam further notes that the material to be memorised dictates the strategies used. The article also reports research undertaken by Rubin-Rabson (1940), which describes the learning techniques used by ‘neurotypical’ musicians. Rubin-Rabson found that the process of breaking down large memorisation tasks into small chunks facilitates learning. However, with people on the autism spectrum, there is a debate in the literature concerning local versus global learning and information processing. The ‘weak central coherence’ theory (Frith, 1989) suggests that autistic people demonstrate a detail-focused processing style and a bias against global processing; however, more recent studies have challenged this theory. Happé and Frith (2006) describe mixed findings regarding weak global processing in autistic people.

In relation to music, the *Chromatic Blues* research (Ockelford, 2012, p. 295) provides an example of a savant having difficulty with elements of global processing. In this experiment, DP, despite being able to reproduce the detail of the complex chromatic harmonies in the piece with a high degree of fidelity, nonetheless makes what appear to be elementary errors in the order in which the main sections appear. This is despite only ever hearing the piece all the way through, so the global structure was constantly being reinforced. Hence a task in which DP is asked to learn new material 'a bit at a time' would be likely to reinforce this area of cognitive challenge.

Specifically, in this study (involving *Classical Turn*), it is hypothesised that:

1) DP, unlike the 'neurotypical' musicians, would find the process of learning a piece by hearing and playing small segments more difficult than listening to the entire stimulus and trying to recreate it in full.
2) Dividing the piece in small chunks would exacerbate his tendency to be 'detail-focused' and maybe result in him failing to grasp the overall structure of the musical piece.
3) DP's tendency of enhanced attention to detail would mean he performs better at repeating back single bars than (the same bars) in the piece as a whole.
4) Somewhat counterintuitively, DP would perform worse when asked to use the 'a bit at a time' protocol than when he heard a piece consistently all the way through ('Listen and Play' protocol, *Chromatic Blues*).

If DP scores the same in the individual segments when attempting to reproduce the stimulus 'a bit at a time' as when playing back the whole piece, and if the overall structure were not to be reproduced correctly, this would provide evidence that his local processing is stronger than his global processing, because it would seem that the latter was not having an impact on or interfering with the former. This would suggest that global processing does present a problem for DP. Therefore, as part of the analysis, DP's scores for each bar, for each of the two different methods, will be compared against each other.

A constraint of the design of the experiment was that, in order to ascertain how DP's grasp of the piece as a whole was progressing; it was necessary for him to attempt to play the whole piece through as part of each session. In order to make the *Classical Turn* study equivalent to the *Chromatic Blues* study in terms of exposure to the stimulus, it was also necessary, in each session, for DP to hear *Classical Turn* all the way through (without interruptions). Hence, although the protocol was *largely* 'a bit at a time', the inevitable contamination from hearing and performing the piece all the way through made it reasonable to predict that this would weaken the effect of having DP listen to and perform the piece 'a bit at a time' (as opposed as all the way through).

4.4 Research questions

The research reported in this chapter addresses Research Question 2:

Learning and memory in music

Given that savants typically learn pieces intuitively, by listening and playing:

2) To what extent and in what ways is DP's capacity to learn music by ear affected by the mode of presentation? Specifically:

> 2a) What impact (if any) does the (enforced) strategy of breaking a memorisation task down into small chunks and learning 'a bit at a time' have on DP's learning and recall (compared with learning a piece 'all the way through')?

4.5 Method: musical memory test – *Classical Turn*

4.5.1 Musical Stimulus

The musical stimulus *Classical Turn* was specially composed by Adam Ockelford, and matched with *Chromatic Blues* (Ockelford, 2012) as far as possible for number and density of events and structure. This enables a level of equivalence allowing comparisons to be made between DP's performances and conclusions to be drawn as to which learning method is most effective for him and determine in which of the above tasks he performs better. The name *Classical Turn* was chosen as it was believed that DP would be able to remember it easily. It was important to create new material because it is difficult to find pieces that one can safely assume DP has not heard before (he is not able to say consistently whether he knows a piece or not just by being told its title). Moreover, composing original pieces makes it possible to control for style, structure and length. As was the case with *Chromatic Blues* (Ockelford, 2012), the following criteria were used to inform the composition of *Classical Turn* (determined through an awareness of the repertoires with which DP is known to be acquainted, and informal accounts of his memory and technical ability).

a) The style should be broadly familiar to DP
b) There should, in addition, be specific features that are unusual within the style, offering higher degrees of salience
c) The piece should be of sufficient difficulty for DP to find it challenging though possible to learn after a number of hearings, given its complexity
d) It should be well within his capacity to play, so that technical considerations should not interfere with issues of music-processing

The key issue in experimental design was to present DP with material that was sufficiently challenging to lie beyond the limits of his immediate powers of recall, but without it being too difficult. This is because the greatest insights into DP's musical processing occur at the point at which the limits of his learning abilities are reached: what follows is essentially an error analysis.

Figure 4.1 below shows *Classical Turn*; this was recorded digitally using a Korg SP-200 88 note touch-sensitive hammer action keyboard. The music played was recorded digitally by the keyboard being linked to a laptop computer, via a MIDI (M-Audio MidiSport Uno – 1-in/1-out – USB/MIDI) interface, monitored through M-AUDIO StudioPro 3 speakers. The accuracy of the rendition was verified through the production of a further score using MIDI-based notation software (Sibelius 5).

Classical Turn

Fig. 4.1 *Classical Turn*. This musical piece has the structure: $A_{1.1}$ $B_{1.1}$ $A_{2.1}$ $B_{2.2}$ C, the same as *Chromatic Blues* (*cf.* Figure 5.4, Chapter 5).

For the purposes of comparison, Figure 4.2 shows *Chromatic Blues.*

Fig. 4.2 *Chromatic Blues.* This musical piece has the structure: $A_{1.1}$ $B_{1.1}$ $A_{2.1}$ $B_{2.2}$ C, as in *Classical Turn* (*cf.* Figure 4.1).

4.5.2 Timetable

The timetable for the sessions conducted with DP is given below (Table 4.1). The intention was to use the same pattern of sessions that had been used for *Chromatic Blues* (Ockelford, 2012) (and this pattern was also maintained for the verbal memory test (see 5.3.3) for comparison purposes). However, there were some slight differences in the number of days between sessions due to participants' schedules. The experiment comprised 14 sessions, equivalent to 27 trials. Five sessions were held in the space of around two weeks, followed by a month's break, and then a further five sessions in the subsequent two weeks. Another session was held after approximately three months, another after six months, after one year and a final session two years later. Hence, data gathering took place over a period of approximately four years.

Table 4.1 DP's pattern of sessions for the *Classical Turn* experiment.

DP			
Session number	*Trials*	*Days since previous session*	*Periods between sessions*
1	1	-	2 weeks
2	2&3	2	
3	4&5	5	
4	6&7	2	
5	8&9	7	
6	10&11	25	1 month
7	12&13	2	2 weeks
8	14&15	6	
9	16&17	2	
10	18&19	5	
11	20&21	96	3 months
12	22&23	190	6 months
13	24&25	422	1 year
14	26&27	735	2 years
Total	**27**	**1499**	**4 years**

4.5.3 Procedure

During the first session, DP was asked to listen to the whole of *Classical Turn* a bar at a time, and then play back each fragment immediately after hearing it. The whole piece was then played to him, but he was not asked to repeat this. In subsequent sessions he was first asked to play what he could remember of the whole piece. He then listened to the piece a bar at a time, playing back each section immediately. Finally, he listened again to the whole piece in its entirety, without subsequently playing anything. This means that in session 1 only one trial took place (the 'bit at a time condition'); all the following sessions consisted of two trials (the 'whole piece' and the 'bit at a time condition').

Session 1:

1. DP listens and plays a bar at a time.
2. DP listens to the whole piece.

In more detail:

Sequence	Instructions
1.	AM says: *'Hi Derek, how are you? Are you ready to start the experiment?*
2.	Following his approval, the experiment begins.
3.	AM says: *'Now Derek you have a go, here is the first bit, please listen and play'.*
4.	AM plays the music.
5.	DP listens to the first bar and plays the music back.
6.	DP listens and plays following the same protocol until the last bar.
7.	AM says: '*Thank you Derek, now here is the whole piece, just listen.'*
8.	AM plays the whole piece, but DP is not asked to play it back.
9.	AM thanks DP.

From Session 2 to Session 13:

This procedure was followed for all subsequent sessions.

1. DP plays the whole musical piece.

2. DP listens and plays ‘a bit at a time’.

3. DP listens to the whole musical piece.

In more detail:

Sequence	Instructions
1.	AM says: *‘Hi Derek, can you please play what you can remember of the Classical Turn?’*
2.	DP plays the piece
3.	The experiment follows the same format as for ***Session 1,*** parts 3–9.

Location: The majority of the sessions involving DP were held at a registered care home in Surrey where he lived at the time. The remainder took place at DP’s mother’s home in Berkshire. These places were chosen because DP is familiar with and comfortable in them, although they are not entirely distraction-free. The aim in using these settings was to facilitate his performance.

Participant: Derek Paravicini.

Experimenter: Annamaria Mazzeschi.

Observer: Adam Ockelford.

Equipment: The results were captured in MIDI format using Cockos’ Reaper Audio-MIDI workstation software, which provided Reaper files and then standardized into MIDI event data (cf. 3.5.5). The keyboard was the same Korg SP-200 88 note touch-sensitive hammer action keyboard on which *Classical Turn* was originally recorded, connected to a laptop. The computer had Sibelius 5 music software. A backup audio recording was made using the Audacity programme, in order to record the performed sounds during the experiment. This programme acted as a backup recording device to the main recording equipment. The sessions were also recorded in audio format using a digital recorder and a video camera.

4.5.4 Method of analysis

After DP had completed each trial, the Cockos’ Reaper data files were converted into Standard MIDI Files (SMF) so that they could automatically be imported to the notation software (Sibelius v. 5) used for the analyses (see Figure 4.3).

Each set of data was edited, as the representation of the non-quantised MIDI data that were captured did not give a clear visual representation of the timing with which participants responded; also some notes did not 'switch off', and these continuations were subsequently ignored (see Figure 4.3). By editing the MIDI file, the data could meaningfully be represented in standard music notation (see Figure 4.4). A professional musician tidied up each trial, also checking with the audio and video recordings in order to verify what she had written.

Fig. 4.3 Musical data recorded by Sibelius programme converted into Standard MIDI Files (SMF).

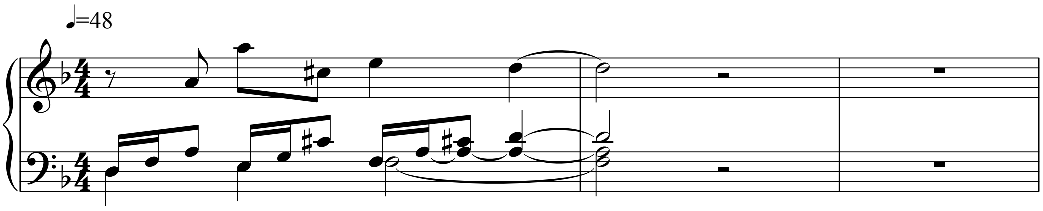


Fig. 4.4 Musical data with the rhythm tidied up in Sibelius.

After the rhythmic tidying-up was completed, the excerpts were analysed. The analysis of the results was undertaken using 'zygonic' theory (Ockelford, 2005). Zygonic theory offers a method of musical analysis first proposed by Ockelford (1991), which enables the degree of imitation between a musical stimulus and its corresponding response to be gauged. It is a particularly useful approach to take in researching savants, since it does not require the research participants to make verbal responses to questions (which are likely to be problematic). Rather, by analysing the musical sounds they produce in response to other sounds, the researcher may be offered insights into the functioning of their musical minds.

The notes produced in DP's responses are compared to the notes in the stimulus in relation to these variables:

1) the potential number of relationships between the stimulus and response
2) the number of relationships of pitch in which the response was judged to have been derived from the stimulus
3) the number of relationships in the domain of perceived time in which the response was judged to have been derived from the stimulus

The potential number of relationships is determined by the number of notes in the stimulus + the number of notes added in the response that were not in the stimulus. With regard to pitch, the strength of derivation is measured both in relation to the absolute pitches of the notes themselves as well as to the differences, or intervals, between successive notes. With regard to rhythm, the strength of derivation is gauged in relation to the duration of each note as well as the inter-onset interval between successive notes. The following equation (Ockelford, 2012, p. 256) formalises this analysis:

$$ZYG = \frac{no.\ of\ zygonic\ relationships\ between\ groups}{no.\ of\ actual\ and\ potential\ relationships\ between\ groups} = \frac{\#Z}{\#Rel}.$$

Zygonic analysis can be used to interrogate any aspect of music whose derivation needs to be measured. It has been used in the 'listen and play' study (Ockelford, 2012) and in the 'play along' study (Grundy and Ockelford, 2014). In the case of the current study ('a bit at a time'), just as in 'listen and play' and 'play along', the consideration of pitch (as a combination of pitch-class and octave) and rhythm (duration and inter-onset intervals) were the variables used to ascertain the level of similarity between the stimulus and the response. The algorithm utilised to ascertain the zygonicity in the response from the stimulus is set out below (from Ockelford, 2012, pp. 256–257).

1. With regard to rhythm: align the two series of 'onset + duration' events to ensure maximal congruence. Events from one series that have no equivalent in the other may be discounted in the matching process that follows (Stage 2), though need to be included as spawning 'potential rhythmic relationships' (in Stage 3). If an event is omitted, the following onset can be measured from the next most recent event to have occurred, or, in the case of two onsets of more, from a new 'data zero'.
2. For each match count 1. For an incorrect duration but correct onset, count 0.5. Total score = #Z(R) (that is, the number of zygonic relationship of rhythm).
3. Let the total number of sequential actual and potential rhythmic relationships between excerpt equal #Rel.
4. The derivation index for rhythm is ZYG(R) (zygonicity of rhythm), where:

$$ZIG(R) = \frac{\#Z(R)}{\#Rel}.$$

5. The derivation index for pitch is similarly determined as follows. Align the two series of pitch events to ensure maximal congruence, if necessary omitting those from either series that have no equivalent in the other.
6. For each match count 1. For an incorrect octave but correct pitch-class, count 0.5. Discounting exact or partial matches involving pitch-class, identify among any remaining pitch events' *intervallic* matches. These must be between sequentially adjacent events; the minimum number of events involved in any intervallic match is two. For each event involved in an intervallic match, count 0.5. The total congruence score is #Z(P).
7. Let the total number of sequential actual and potential pitch relationships between excerpts be equal to #Rel (as in Stage 3

above).

8. The derivation index for pitch is ZYG(P) (zygonicity of pitch), where

$$ZYG(P) = \frac{\#Z(P)}{\#Rel}.$$

9. The derivation index for pitch and rhythm is ZYG(P + R) (zygonicity of pitch and rhythm), where:

$$\mathrm{ZYG(P + R)} = \frac{\#Z(P) + \#Z(R)}{\#Rel\ X\ 2}.$$

This procedure takes each note of DP's response separately in relation to pitch and rhythm and ascertains to what extent this can be considered to derive from the corresponding note in the stimulus. The analysis is carried out separately in relation to three strands in the texture: the melody (at the top), the inner parts (considered as a single item), and the bass-line (at the bottom). Below there is an example (see Figure 4.5) of how zygonic analysis has been performed with regard to the first bar in the top part of the melody.

Trial 1, bar 1, top part, WP

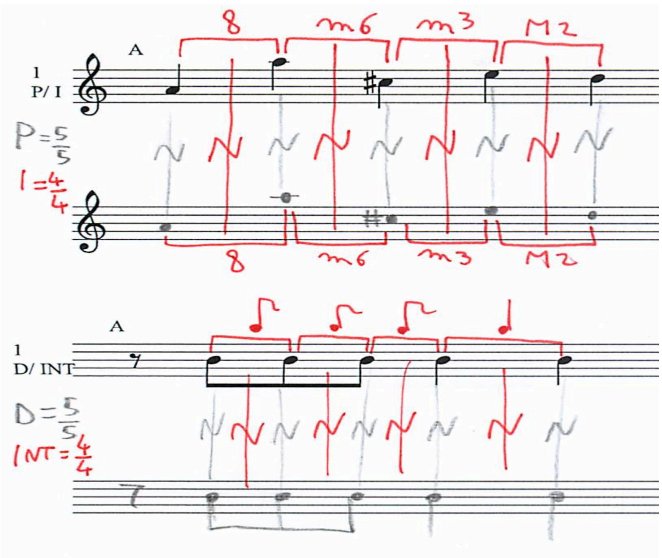


Fig. 4.5 Example of zygonic analysis.

The number of potential relationships between the stimulus and the response for pitch (note) / pitch(interval) and rhythm(duration) / rhythm(inter-onset interval), is recorded just once, as the number of potential intervallic relationships (for both pitch and rhythm) equals just the number of potential relationships minus one.

In the analysis the denominator of the fraction (establishing the number of possible relations) is mainly dictated by the response, and often is similar, meaning that he has played the same number of notes.

After the zygonic analysis was performed, the results were reported using a spreadsheet to map data across trials (See Table 4.2). The pitch ratio is calculated by:

$$\frac{\dfrac{\#\,Pitch\ (Note)\ zygonic\ relationships}{\#\,Potential\ number\ of\ relationships} + \dfrac{\#\,Pitch\ (Interval)\ zygonic\ relationships}{\#\,Potential\ number\ of\ relationships - 1}}{2}$$

The rhythm ratio is calculated by:

$$\frac{\dfrac{\#\,Rhythm\ (Duration)\ zygonic\ relationships}{\#\,Potential\ number\ of\ relationships} + \dfrac{\#\,Rhythm\ (Interval)\ zygonic\ relationships}{\#\,Potential\ number\ of\ relationships - 1}}{2}$$

Table 4.2 Excel spread sheet first bar.

Classical Turn						Bar 1				
			Potential no. of rels	Pitch/Note zygonic rels	Pitch/Interval zygonic rels	Rythm/dur zygonic rels	Rythm/int zygonic rels	Pitch ratio	Rhythm ratio	Total ratio
Session number	1	Top	5.0	5.0	4.0	5.0	4.0	1.0	1.0	1.0
Trial number	1	Inner	7.0	6.0	4.0	4.0	2.0	0.8	0.5	0.6
20090714		Bottom	3.0	3.0	2.0	3.0	2.0	1.0	1.0	1.0
"a bit at a time"		Total/Average	15.0	14.0	10.0	12.0	8.0	0.8	0.7	0.8

Unlike in the chord experiment, the probability of playing a fragment of melody that matches the stimulus by chance is remote, so no correction to the raw data is applied (*cf.* 3.5.8).

Following the findings of the *Chromatic Blues* experiment (Ockelford, 2012, pp. 280–281), it is anticipated, particularly in the early trials of *Classical Turn*, that there will be passages in what DP produces that are not directly related to anything in the stimulus. Here, the approach will be taken of the 'best fit' in aligning any fragments in which derivation seems to have occurred. Of course, there is a danger here of 'reading into' the material, that DP produces relationships that did not actually feature (consciously or non-consciously) his learning and recall. Ockelford's probabilistic analysis (op. cit., pp. 252–253) shows that, melodically, a series of three notes or more is unlikely to resemble a comparable motif in the stimulus by chance, however.

It may be the case that one interval is the same size as another, but has the opposite polarity. For example, in the stimulus there may be an E followed by a D (an ascending major 2^{nd}) while in the response there may be a D followed by an E (a descending major 2^{nd}). In circumstances like this, the relationship will be deemed to be partly imitative and will be given a derivation index of 0.5.

It may also be the case that successive notes in the stimulus appear simultaneously in the response, that is, when a melodic interval (pitch) becomes a harmonic one. In these circumstances, it would not be possible to have a general rule that determined which one of the two notes that were played together should be connected in analysis with the one that precedes or follows. Here, the use of musical experience and intuition are used to determine the analytical order of events. The interval E♭ to B was preferred analytically to the interval A to B (see Figure 4.6) as this sequence of events occurred in the stimulus.

Trial 1, bar 2, inner part, BT

Fig. 4.6 Example of analysis.

Within the stimulus some of the bars were the same. Hence, for these bars the response noted in the analysis could be labelled in two ways. In order to identify which of these identical bars DP was playing, the analysis focused on what he played before and after each bar. Furthermore, when the analysis was made the order in which the bars were played was maintained, (see Appendix III for example of zygonic analysis).

4.6 Results

4.6.1 Analysis of 'the whole piece' condition (WP)

Figure 4.7 shows the results for WP. The *x-axis* displays the trials number, and the *y-axis* represents the Derivation Index (DI) (the degree of imitation between the stimulus and response *cf.* 4.5.4). Looking at Figure 4.7 it is evident that a fivefold improvement occurs during the first four sessions in which DP plays the whole piece through (sessions 2, 3, 4 and 5), with little change (0.1) between trial 2 and 4. Following a break of one month, DP's performance falls back to a level close to his first attempt. However, there is a general improvement in the four sessions that follow, although it is not until trial 18 that DP manages to reach a Derivation Index greater than 0.3 again. A break of three months follows before trial 20, when DP's score once more falls back slightly to 0.26. Thereafter following intervals of six months, one year and two years DP's scores stabilise around 0.28. There appears to be something of an anomaly here, in that the scores DP achieves in the 8th and in the 18th trials are never achieved again. Overall, DP's success in remembering the whole piece is surprisingly poor, in relation to his success in remembering much of *Chromatic Blues* (see in Chapter 6). Evidently, having the piece broken up into small chunks not only fails to facilitate his learning, but actually has a detrimental effect.

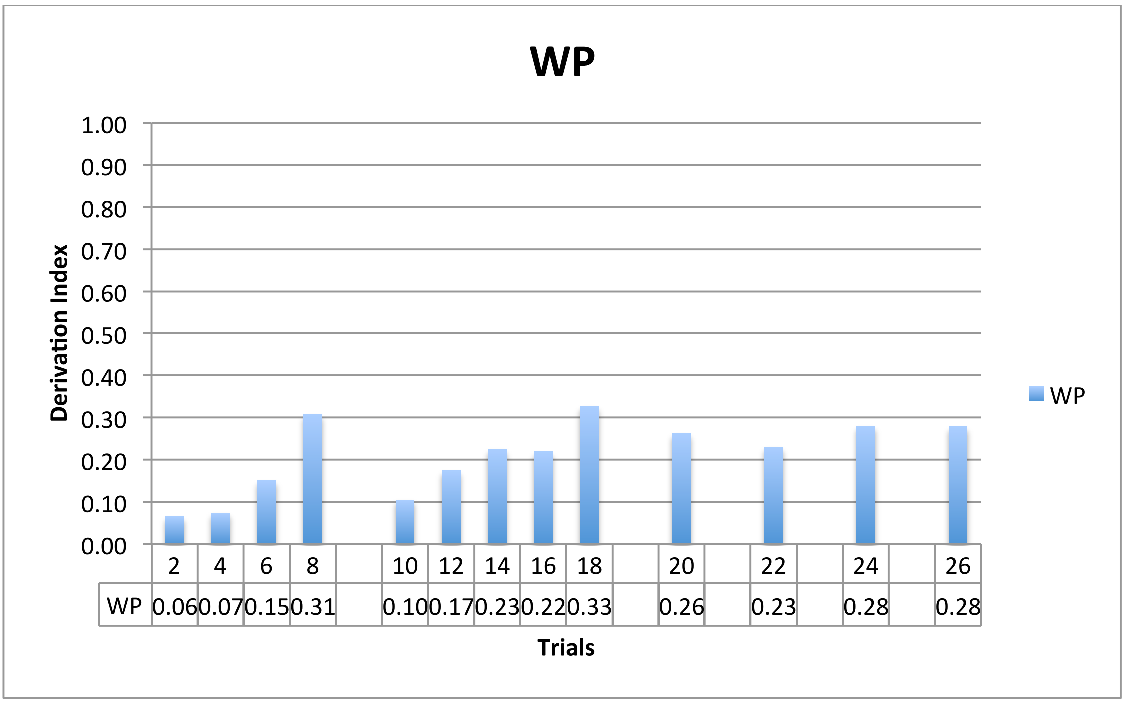


Fig. 4.7 Results for WP.

Table 4.3 sets out the number of bars played in WP. Due to the repetitive structure of *Classical Turn* (see Figure 4.1), the following rules have been used: the bars ascribed (i.e. either 1–3 or 9–11) are dependent on the material that followed in DP's response. The first column shows the number of the sessions; the second column indicates the number of trials; the third column displays the number of bars played during the whole piece. The numbers highlighted in bold in the fourth column represent the consecutive bars played; the last column describes the order in which they were played (when DP did not play them in sequential order). During WP, the bars played became increasingly fixed, comprising consecutive batches. At no stage does DP play more than 12 bars, although all appear at one time or another.

Table 4.3 The bars played in the 'whole piece condition' (WP).

Session	Trial	Number of bars played	Bars played	Order of bars played (when out of sequence)
2	2	4	1,3,**18-19**	
3	4	4	1,3,**18-19**	
4	6	7	**1-2**,9,11,**16-17**,19	1,2,9,17,18,16,19
5	8	12	**1-6**,**10-11**,**16-19**	1,2,3,4,5,6,18,19,17,10,11,16
6	10	5	**1-4**, 19	
7	12	8	**1-4**, **10-11**, **18-19**	
8	14	9	**1-4**, **10-11**, **17-19**	1,2,3,4,17,10,11,18,19
9	16	8	**1-6**, **18-19**	
10	18	11	**1-8**,**17-19**	
11	20	8	**10-15**, **17-18, 19**	17,18,10,11,12, 13,14,15,19
12	22	9	**9-14**,**17-19**	
13	24	10	**9-15**,**17-19**	
14	26	10	**9-15**,**17-19**	

Some of these bars could unambiguously be ascribed to single sources in the stimulus. Others are made up of fragments from different places (see Figure 4.8) – an approach that DP also adopts in *Chromatic Blues* (*cf.* Chapter 6). In these cases, the bar that makes up the majority of the material – that is the best possible fit – is cited as the source in Table 4.3. Figure 4.8 displays the stimulus (top stave) and the response (bottom stave) for bar 3 of trial 3 (BT). This bar is an example of DP apparently adding material from other bars, since he seems to borrow the turn from bar 2. In terms of the analysis, where a continuous line appears, this indicates that the response is correct; a broken line (or in some cases no line) denotes that it is incorrect. 'P' means pitch. The denominator of the fraction represents the potential number of relationships between the stimulus and the response (i.e. in trial 3 there are 10 possible relationships). The numerator is the actual score DP achieved (i.e. in trial 3 playing 5 notes correctly). Hence the derivation index (DI) is 5/10 = 0.5. 'I' means interval. The denominator in the fraction (9) is the number of intervallic relationships between the stimulus and the response; the numerator in the fraction (3) is the correct number of intervallic relationships detected by DP. Here the DI is 3/9 = 0.33. The average DI is 8/19 = 0.42.

Trial 3, bar 3, top part, BT

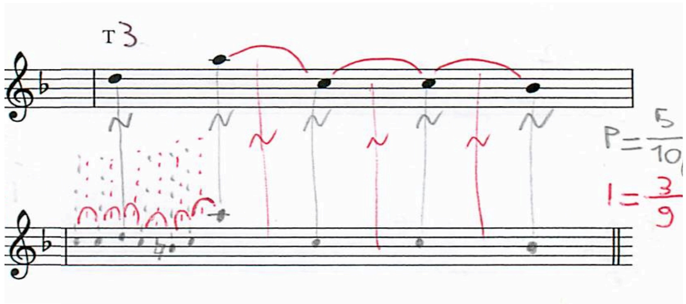


Fig. 4.8 Fragment ascribed to specific bar.

Looking at the structure as a whole, DP invariably recreates material from the beginning of the piece (or a proxy of it – since bars 9–11 are the same as bars 1–3) and from the end – that is, the 'primacy' and 'recency' effect that one would expect in learning tasks (Postman and Phillips, 1965). This is thought to be because material that occurs at the beginning or end of a sequence has less that is adjacent to potentially interfere with it in memory.

It is striking, looking at the data as a whole, that DP's responses improve more as a consequence of his capacity to recall a greater number of bars than the fidelity with which individual bars are remembered. This is shown (see Figure 4.9) by the high correlation between the number of bars recalled and the average derivation index per trial WP ($r = 0.96$, $p < 0.0001$).

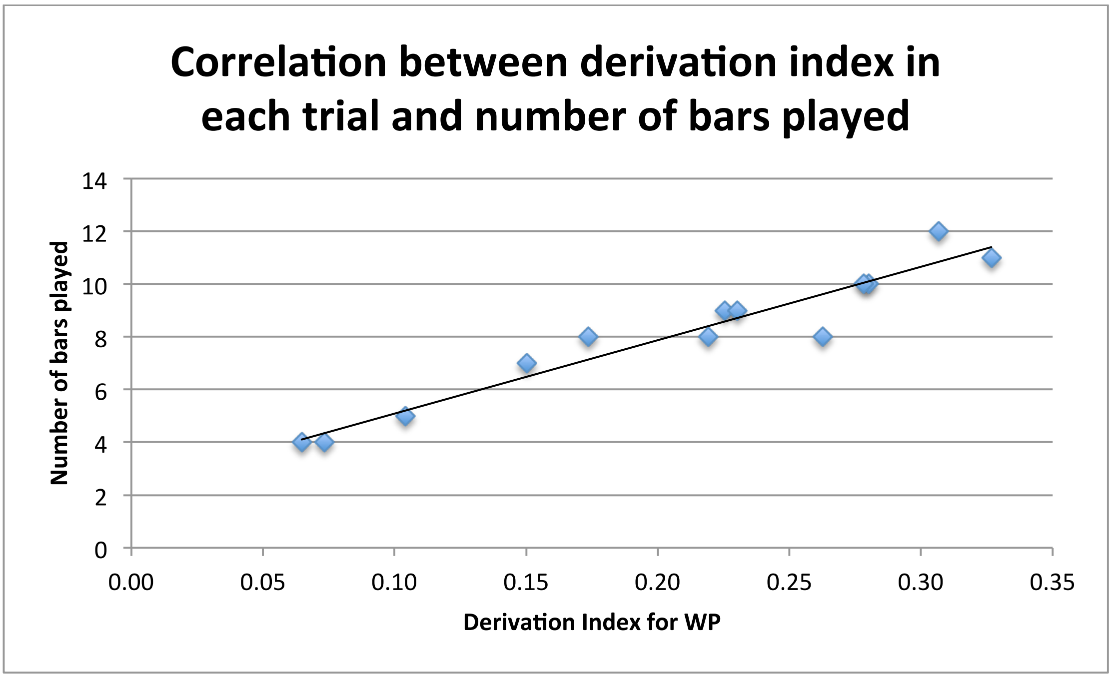


Fig. 4.9 Correlation between derivation index in each trial and number of bars played.

That is to say, he consistently makes the same or similar errors across most of the trials – his improvement comes about as a result of the *quantity* of material he recalls rather than its *quality*. Just how this finding sits alongside work, for example, by van den Berg, Awh and Ma (2014), which found a steep decrease of mean precision with increasing set size in working memory, remains a topic of future research.

4.6.2 Analysis of 'a bit at a time' condition (BT) and comparison with WP

Looking at the graph as a whole (Figure 4.10) the striking thing is that DP's renditions pertaining to BT are far lower than anticipated, given his AP ability and experience in learning pieces rapidly by ear, although, as one would expect, they are higher than in WP. Moreover, he makes only a slight improvement across the trials, with his DIs ranging from 0.55 to 0.68 (an increase of only 0.13). As will become apparent, the reasons for the relatively low scores are to be found in DP's tendency to elaborate on the material provided in the stimulus.

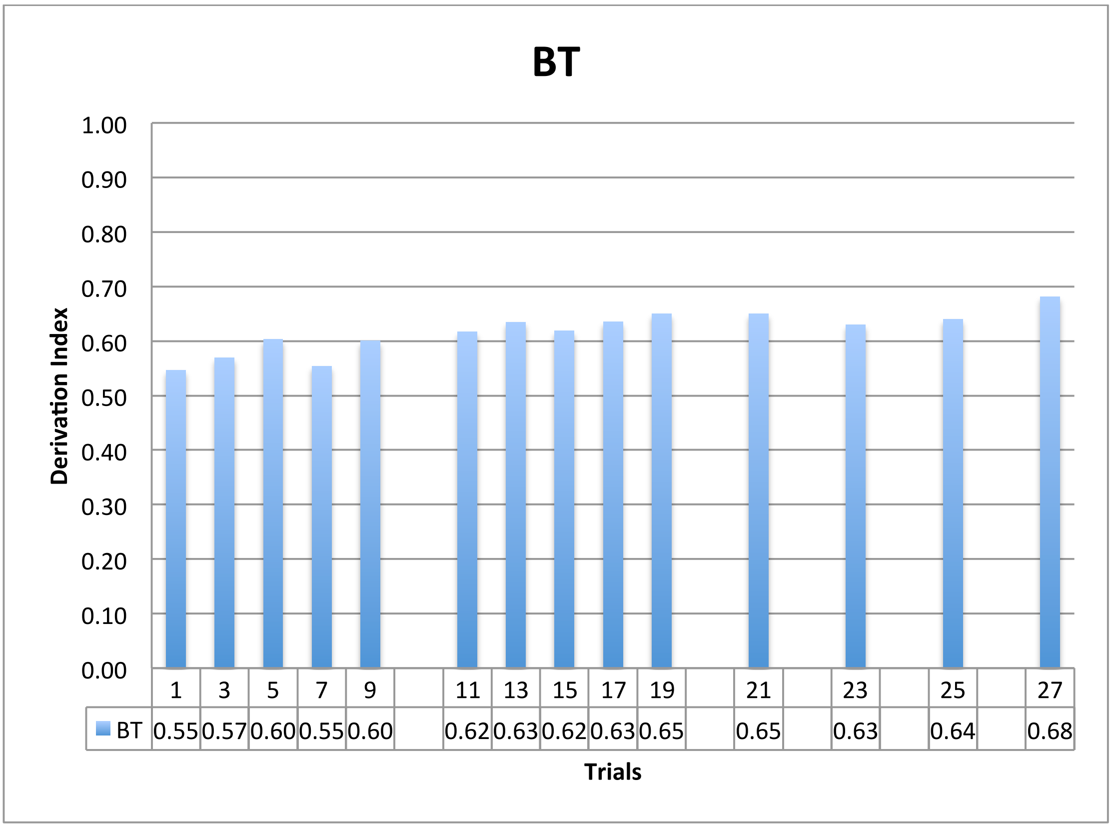


Fig. 4.10 Results for BT.

Looking at Figure 4.11 for both 'a bit at a time' (BT) and 'whole piece' (WP), the data indicate that the results improve slightly as the experiment progresses through the trials. The graph shows that DP was much more successful with BT trials than WP trials (see Figure 4.12 for the overall scores for each condition). For WP, the results varied widely, and improvement through the first two blocks of sessions was marked, but fell back when the time periods between sessions grew. In WP, it was important to take into consideration that as the trials progressed so did the number of bars played and, within that increase, the number that were consecutive (and therefore sequential) grew disproportionately (see Table 4.3). Nonetheless, the amount of material that DP played increased somewhat irregularly.

The results of the BT trials are surprisingly low (although starting from a relatively high score, a DI of 0.55). The progression in learning was small, with DIs increasing by between 0.01 and 0.05, with a final score of 0.68. This comparatively poor performance may be due to systematic rhythmic errors seen in two bars (*cf.* 4.6.4) throughout all the trials.

One might expect that the replication of each bar in the BT condition would be more accurate than the same bar recalled in WP, as the former relies just on strongly working memory and absolute pitch, whereas the latter involves both of these with the addition of long term memory. However, DP's memory of his own attempts at recalling the piece (which were not always correct) seems to have been stronger than his memory for the recorded stimulus. Although DP listened to the piece at the end of each session, his responses consistently included the same errors, which perhaps he learned during the WP trials and carried over into BT trials. It seems that the procedure of playing the WP followed by BT may have confused him. The results suggest that this had a negative impact on his ability to perform well in the BT condition.

The WP data provide overwhelming evidence that even though DP attempted to play the whole piece as well as listening to it all the way through in each session, this was not enough to fix the structure in his mind, and he failed to recognise the repetition within the piece (see Figure 4.1), preventing him from accurately reconstructing the stimulus. This inability to grasp a whole structure is characteristic of savants' memory, which is typically fragmented; savants often demonstrate a thorough attention to detail but can show weakness in processing a whole (*cf.* Chapter 2).

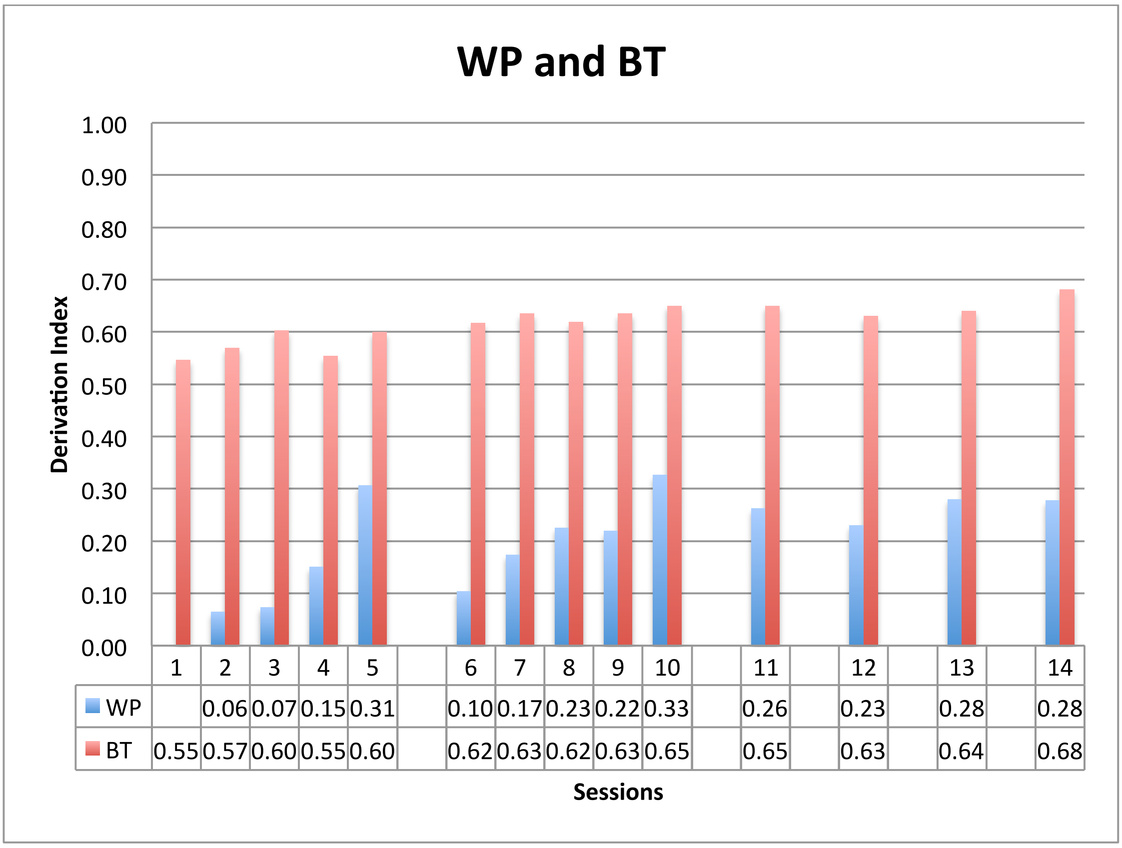


Fig. 4.11 Results for WP and BT.

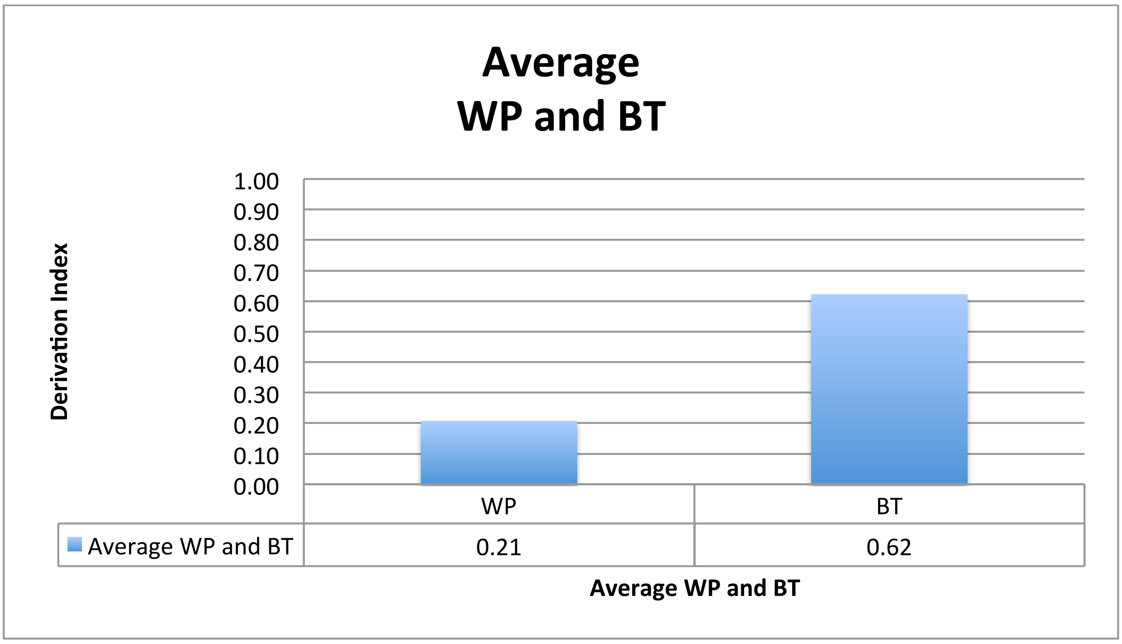


Fig. 4.12 Average DIs for WP and BT.

In a similar experiment (*Chromatic Blues*; Ockelford, 2012) DP's responses were much more accurate. The learning protocol, in which DP listened to the whole piece before being asked to play it back, may well have suited him better; the bar by bar protocol used with *Classical Turn* meant that the structure of the musical piece was less evident. Of course, it may be that, for whatever reason, DP found *Chromatic Blues* easier to learn than *Classical Turn*, despite the efforts to make them similar in complexity, structure and length. This risk is an inevitable feature of the research design. Further comparison with the *Chromatic Blues* study can be found in Chapter 6.

4.6.3 Pitch and rhythm in WP

Figure 4.13 displays DP's recall in relation to pitch and rhythm separately. Taken as a whole, DP performs better in relation to pitch (M = 0.23, SD = 0.10) than in relation to rhythm (M = 0.19, SD = 0.08), $t(12)$ = 4.875, p = .0004 (see Figure 4.14). The only occasions when rhythm is better than pitch is during trials 2 and 4, but here the differences are very small in the context of very high error rates.

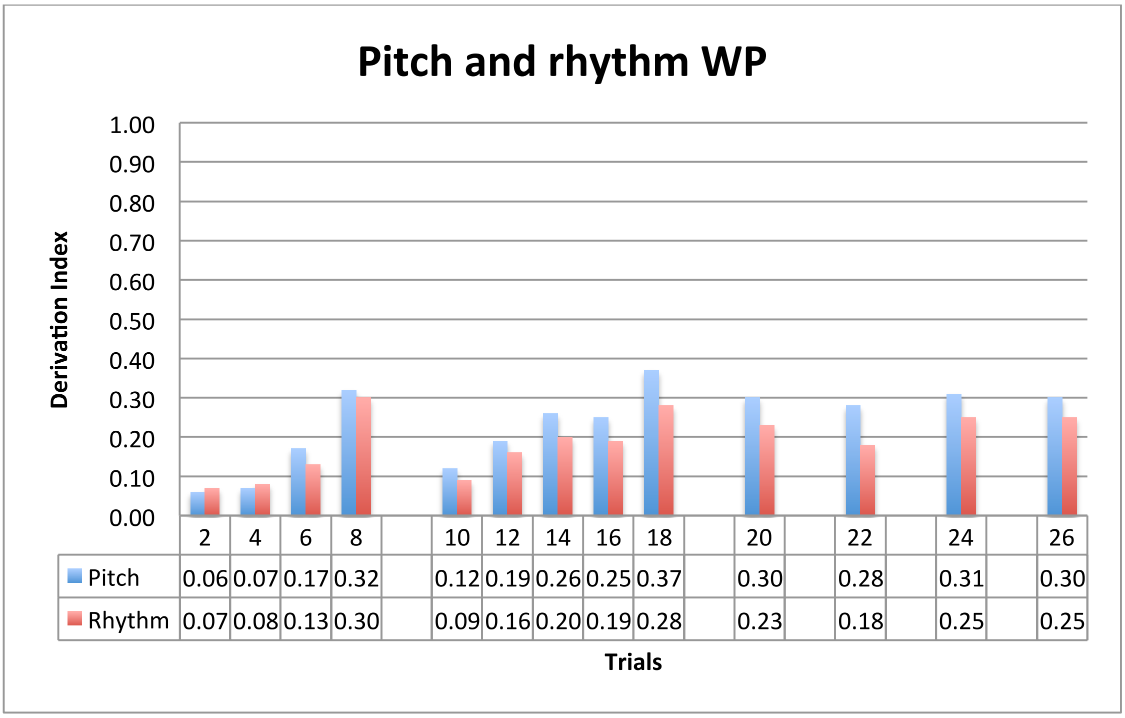


Fig. 4.13 Results for the pitch and rhythm (WP).

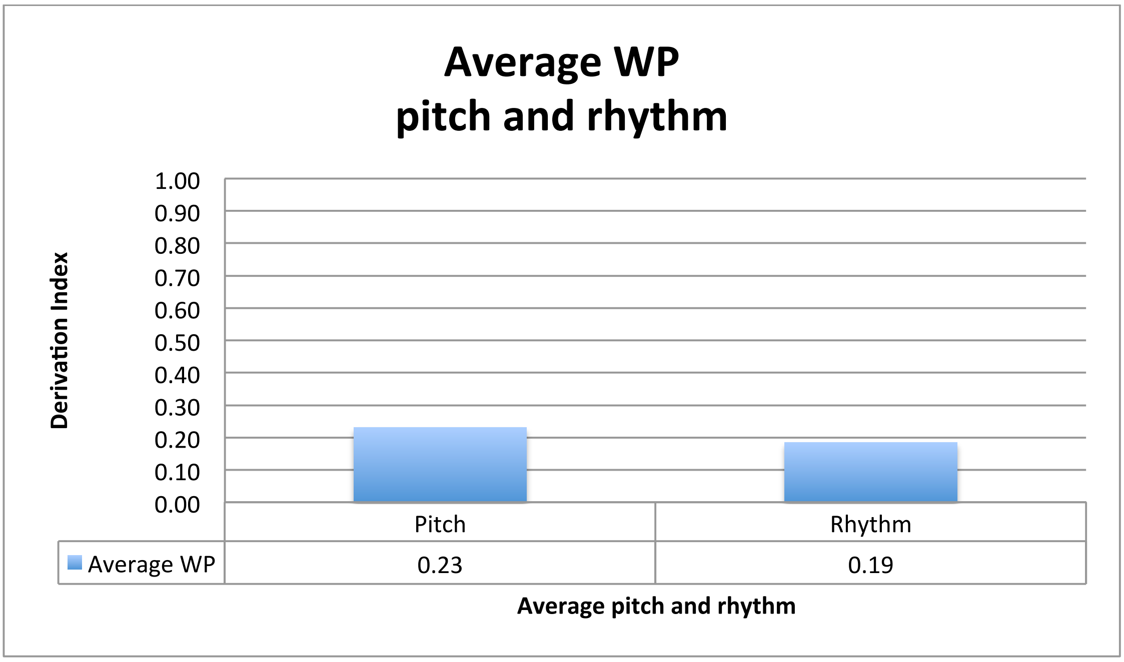


Fig. 4.14 Average for the pitch and rhythm (WP).

This result was not anticipated, since in the previous *Chromatic Blues* experiment (Ockelford, 2012), DP's results were very similar in relation to both pitch and rhythm. Qualitative analysis of DP's renditions of *Classical Turn* show that his relatively poor rhythmic recall is due to persistent errors; for example in both trials (WP and BT) he replaces a quadruplet turn with a quintuplet (see Figures 4.15 and 4.16) (*cf.* 4.6.3). It seems that DP may have heard the swift melodic figure as a 'turn' (an ornament that is often written in music as a special sign above the melody). The turn appears in different styles of Western classical music and it seems that DP may have heard the ornamental notes not as a core part of the melody. This is shown, for example, by him sometimes adding another turn in the melody in bar 1 (at a different though structurally similar point). That is to say, adding notes in this way was not an issue for him in terms of accurate replication. Similarly, just as turns appear in slightly different forms in Western classical music (with a greater number or fewer notes embellishing the core melodic line), so DP chose to add an extra note to the turn heard in the stimulus (maybe because he has the technique to enable him to play very rapidly and he enjoys doing so). Because the turns make up around half DP's response, the impact of these additions on his DIs was considerable.

In Figure 4.15 ‘D’ means ‘duration’ (the length of the note), the numerator of the fraction represents the number of durations DP reproduces correctly (4), the denominator is the total number of durations possible (as established by examining both the stimulus and the response – *cf.* 4.5.4); in this case 10. Hence the DI for duration is 4/10 or 0.4 ‘Int’ means ‘inter-onset interval’: here the numerator represents how many inter-onset intervals DP recognises (3); the denominator is the possible number of inter-onset intervals between stimulus and response (9); and the DI is 3/9 = 0.33. The average of these (that is, the DI for rhythm) is 7/19 = 0.37. Contrast this with the DI for pitch (8/9) and interval (6/8), which equates to 0.82.

Trial 5, bar 10, top part, WP

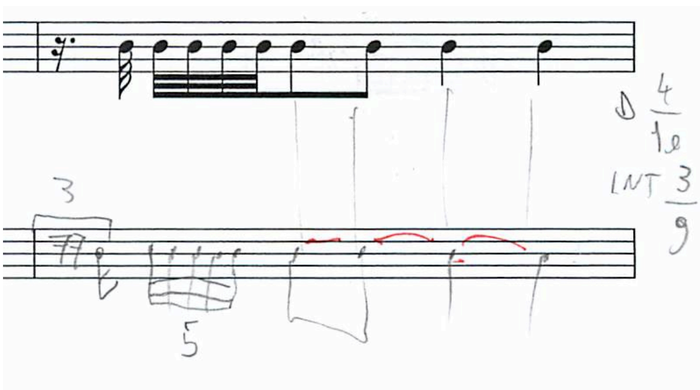


Fig. 4.15 Example of error in which a quintuplet replaces a quadruplet (analysis of rhythm) in WP.

Trial 3, bar 2, top part, BT

Fig. 4.16 Example of error in which a quintuplet replaces a quadruplet (analysis of pitch) in BT.

4.6.4 Pitch and rhythm in BT and comparison with WP

Figure 4.17 shows DP's DIs throughout all the BT sessions in relation to pitch and rhythm. Throughout the experiment there are some fluctuations in the DIs that DP achieves. However, there is a noticeable improvement, from 0.57 to 0.73 for pitch, which is consistently lighter than the score for rhythm (0.53 to 0.63).

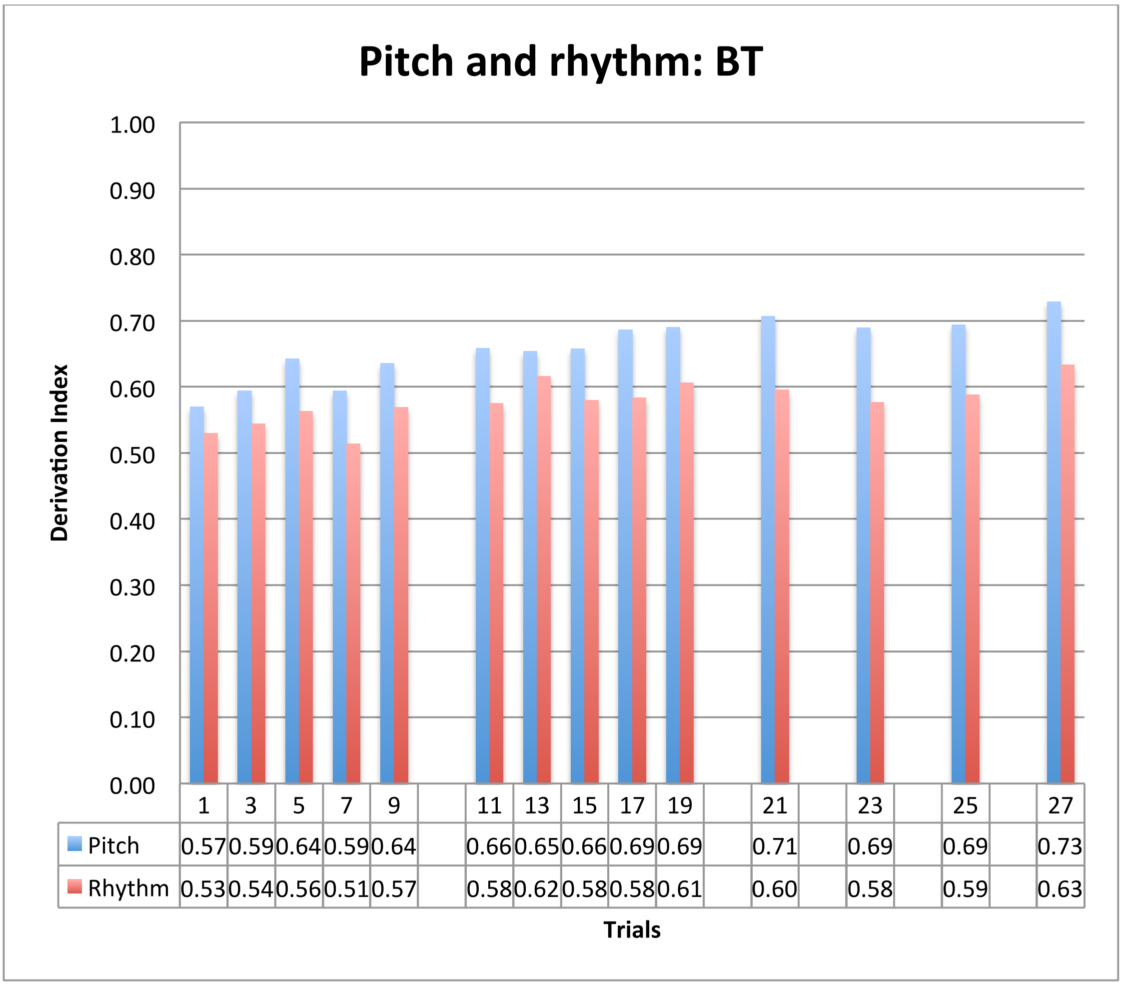


Fig. 4.17 Results for the pitch and rhythm (BT).

Overall, the difference in pitch recall (M = 0.66, SD = 0.05) is significantly better than rhythm (M = 0.58, SD = 0.03), $t(13)$ = 11.64, p = .0001 (see Figure 4.18). This is largely because DP makes recurring mistakes in the rhythm (the transformation of the quadruplet turn to a quintuplet; *cf.* 4.6.3).

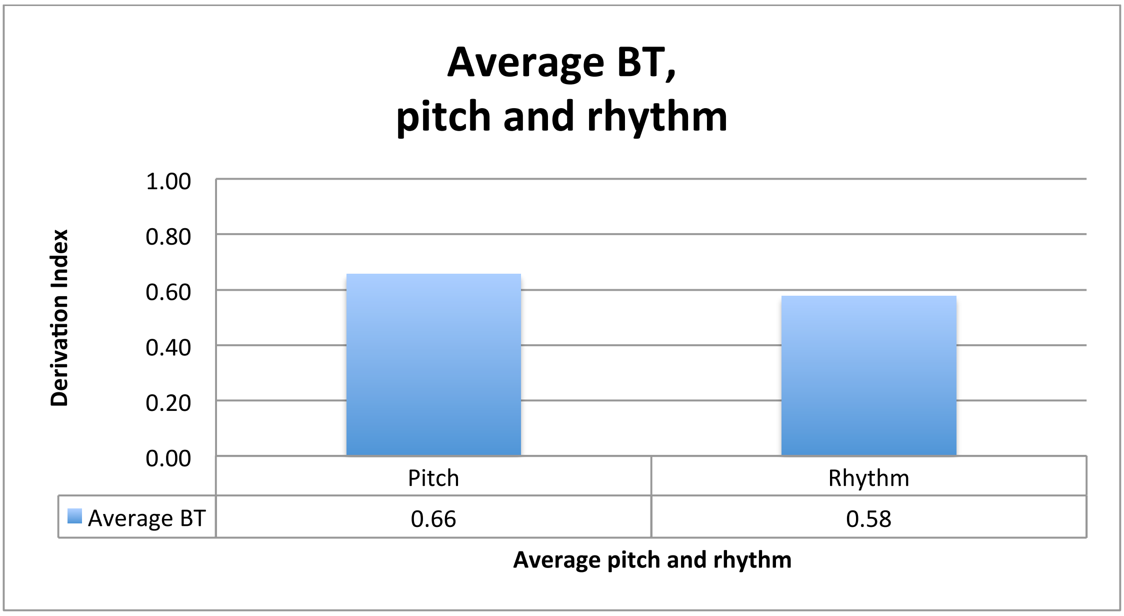


Fig. 4.18 Average for the pitch and rhythm (BT).

For both WP and BT, improvement in DP's DIs is more evident and consistent in the domain of pitch than of rhythm (see Figure 4.19). This is in contrast with the findings from *Chromatic Blues* (*cf.* Chapter 6), which show that pitch and rhythm were recalled with the same degree of accuracy overall.

The difference between pitch and rhythm is probably due to the fact that some systematic errors were made during each trial that might have affected the score for rhythm more than pitch. For example, as noted above, DP consistently added extra notes to the turns that occur in alternate bars throughout the piece, changing them from quadruplets to quintuplets. The impact on the score for pitch was minor because only one note was added on each occasion; the other four were correct. In contrast, this mistake vastly affected the score for rhythm as it meant that there were five incorrect note values and four wrong inter-onset intervals each time it occurred (see Tables 4.19, 4.20 and 4.21 for a list of systematic mistakes in each of the top, inner and bottom parts).

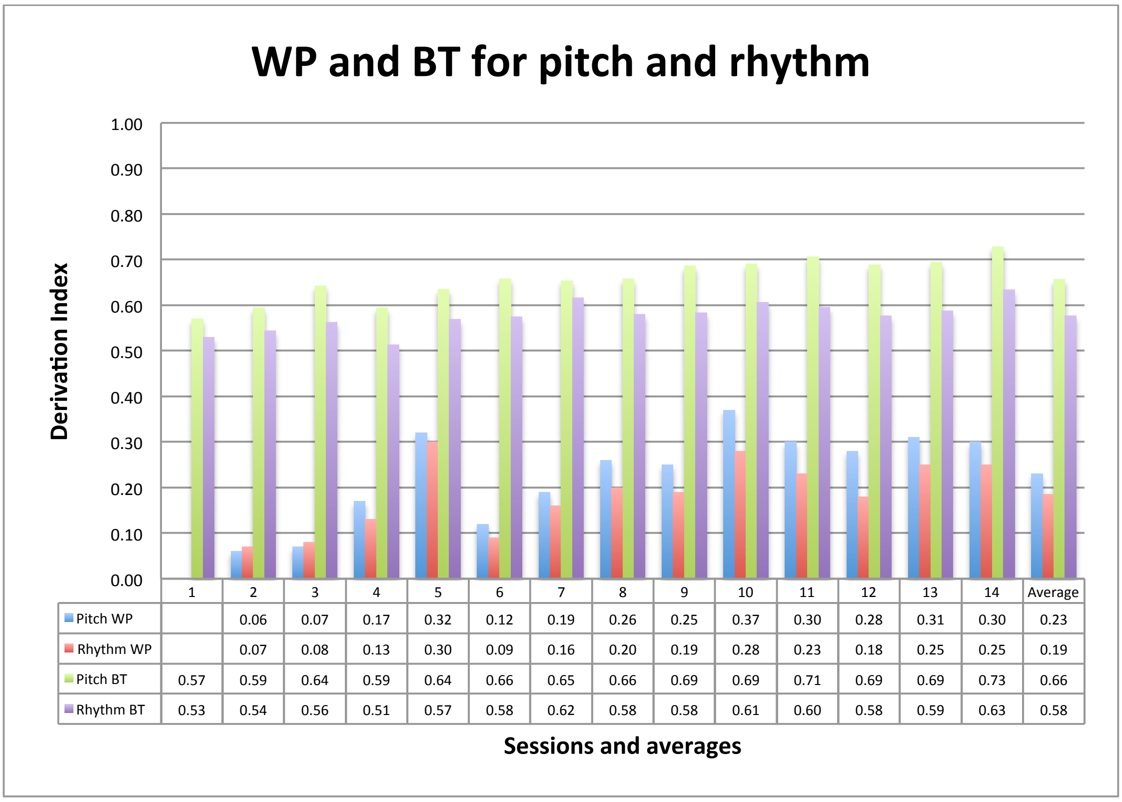


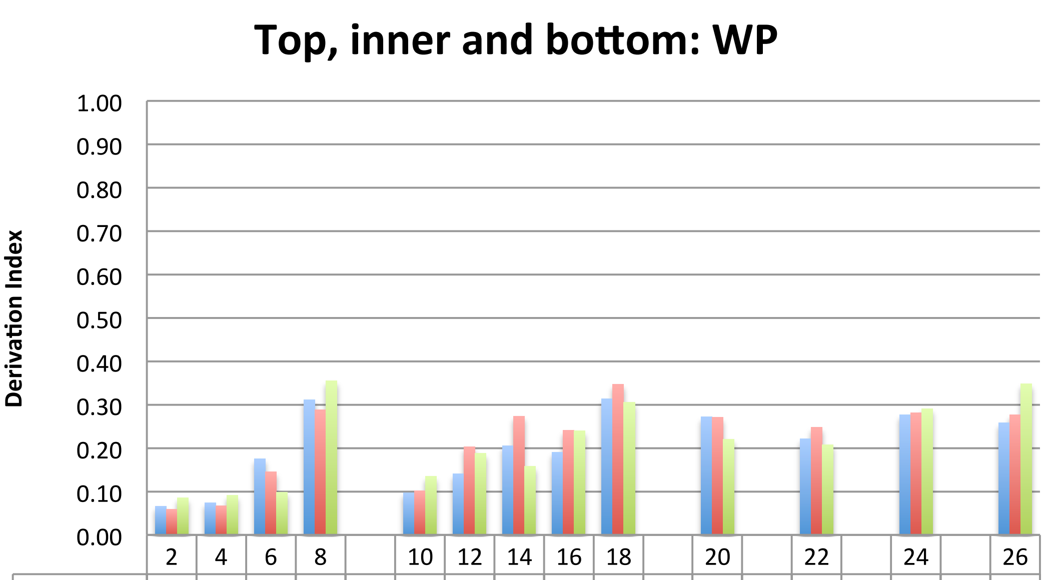
Fig. 4.19 WP and BT for pitch and rhythm.

4.6.5 Top, inner and bottom parts in WP

Looking at the graph (Figure 4.20) the data fluctuate throughout all trials showing an overall improvement. The three variables (top, inner and bottom parts) are highly correlated with one another (see Table 4.4), the differences between the mean DIs of the three strands are very small (Figure 4.21), and the results of a one-way ANOVA demonstrate no statistical differences between the top, inner and bottom parts as a whole.

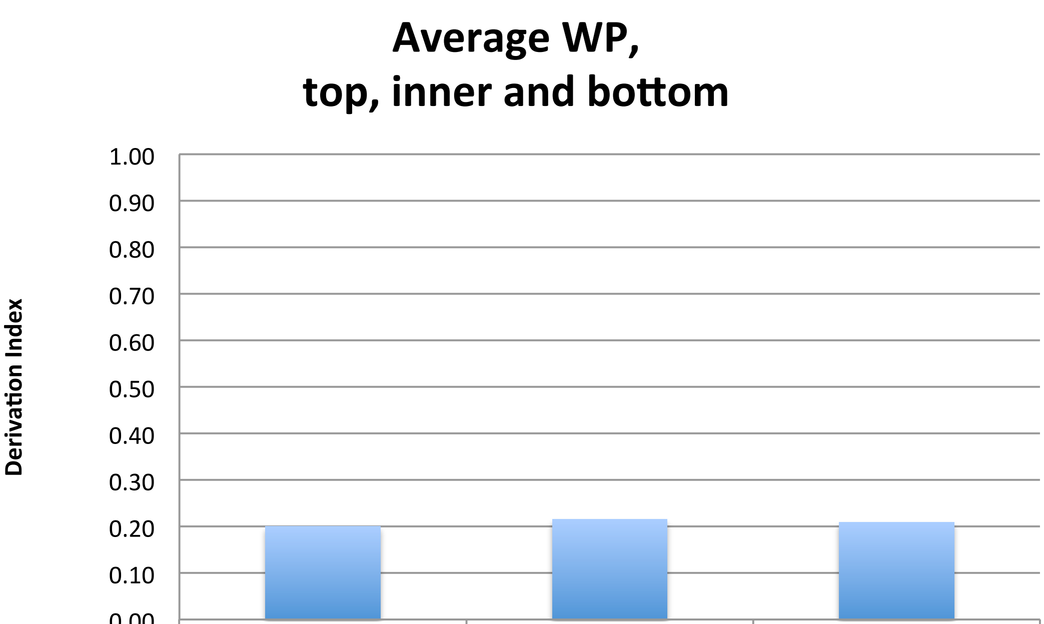
Table 4.4 Correlation Matrix Results. Each correlation coefficient (r) is calculated independently, without considering the other variables.

	Top	**Inner**	**Bottom**
Top	1.0000		
Inner	0.9457	1.0000	
Bottom	0.8655	0.8493	1.0000



	2	4	6	8	10	12	14	16	18	20	22	24	26
TOP	0.07	0.07	0.18	0.31	0.10	0.14	0.21	0.19	0.31	0.27	0.22	0.28	0.26
INNER	0.06	0.07	0.15	0.29	0.10	0.20	0.27	0.24	0.35	0.27	0.25	0.28	0.28
BOTTOM	0.09	0.09	0.10	0.36	0.13	0.19	0.16	0.24	0.31	0.22	0.21	0.29	0.35

Fig. 4.20 Top, inner and bottom parts (WP).



	TOP	INNER	BOTTOM
Average WP	0.20	0.22	0.21

Fig. 4.21 Average for top, inner and bottom parts (WP).

These similarities exist despite the varying number of events in each strand (see Table 4.5).

Table 4.5 The number of events in the stimulus of the top, inner and bottom parts.

Bars	Top parts	Inner parts	Bottom parts
1	5	6	3
2	9	7	2
3	5	10	2
4	9	8	2
5	5	6	2
6	9	7	2
7	5	6	2
8	10	7	2
9	6	6	3
10	9	7	2
11	5	10	2
12	S	S	S
13	5	6	2
14	9	7	2
15	6	7	2
16	9	8	2
17	7	8	4
18	6	10	3
19	1	5	3

4.6.6 Top, inner and bottom parts in BT and comparison with WP

Figure 4.22 displays DP's DIs in the top, inner and bottom parts achieved for the BT trials. Looking at the first five of these, the DI for the bottom part is the highest, followed by the Dis for the top and the inner parts (in trials 1, 3, 5 and 7); in trial 9 the top part's DI is greater than that pertaining to the bottom. From trial 11 to trial 19 there are some fluctuations, with the bottom DI outperforming the other parts just once (15) and the top DI being higher than the bottom DI two times (trial 11 and 13). In the last four trials (21, 23, 25, 27) the bottom DI is the highest followed by the inner and the top DIs. DP achieves a higher DI for the bottom part nine times out of fourteen, similar to the results in the disaggregation of chords experiment (*cf.* Chapter 3). The mean DIs for the top inner and bottom parts are shown in Figure 4.23. The means of the DIs as a whole are statistically distinct $F(2, 13) = 10.96$, $p<.0007$, though of the pairs of differences, only that between bottom part (*M* = 0.66, *SD* = 0.05) and the inner part (*M* = 0.60, *SD* = 0.05) is significant, p<.001. This supports previous findings (see Ockelford, 2012; and Chapter 3), which argued that musical savants tend to focus on the bass line in musical textures comprising more than one part.

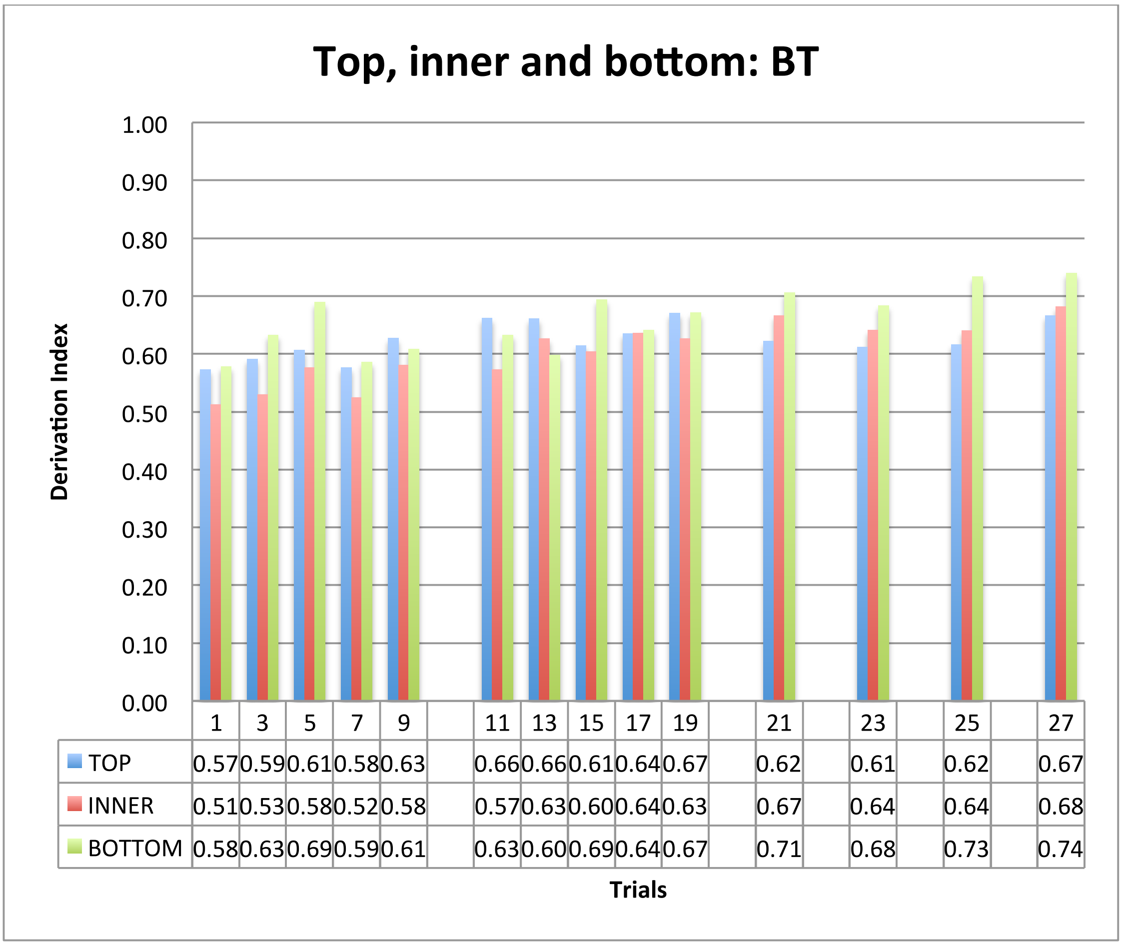


Fig. 4.22 Top, inner and bottom parts (BT).

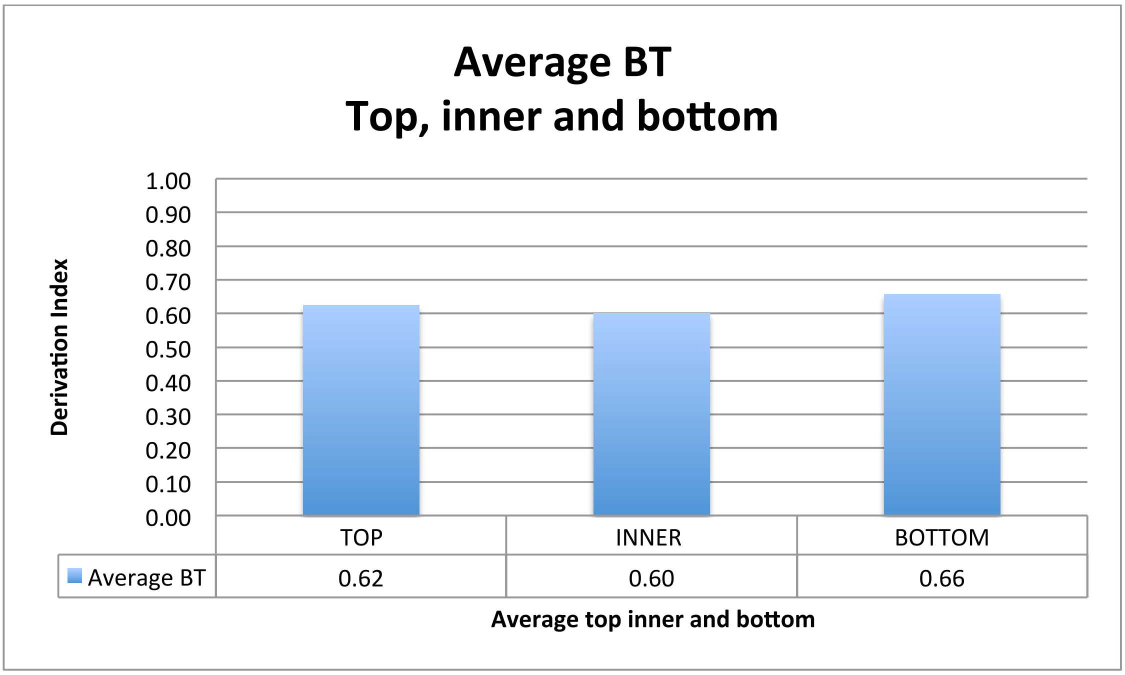
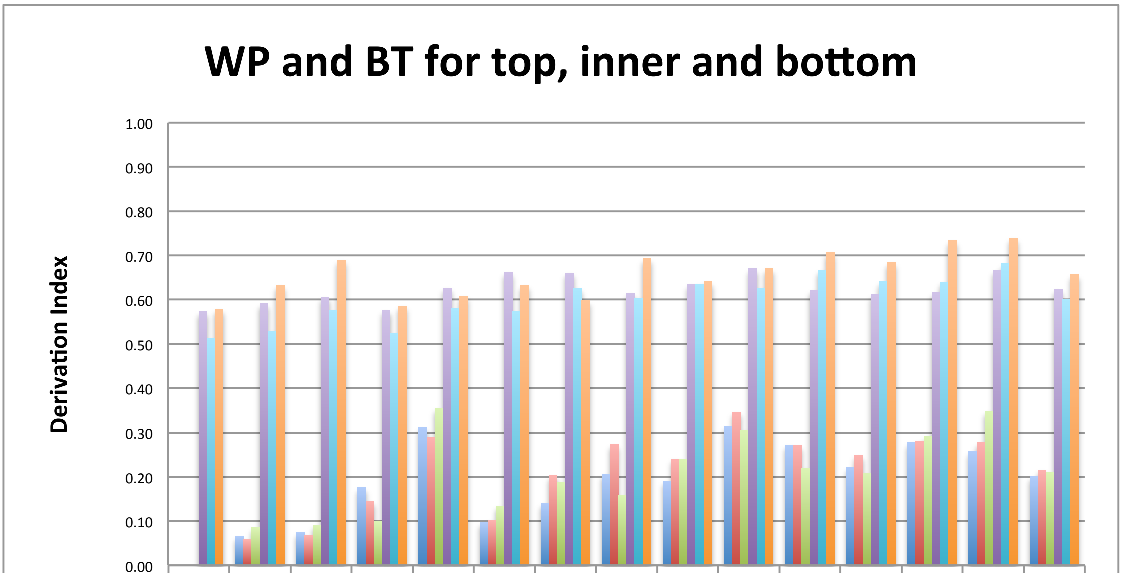


Fig. 4.23 Average for top, inner and bottom parts (BT).

Figure 4.24 compares the DIs for the three parts for WP and BT. The DIs achieved for WP across all parts are essentially equal, whilst in the BT trials DP achieved a higher DI on the bottom part, followed by the top and the inner. The reason why the DIs in WP are lower than BT may be due to the fact that in the WP DP's performance does not include all the bars presented in the stimulus. However, the differences in DI between WP and BT for the three parts may also be a result of his level of accuracy in reproducing pitch and rhythm. One would expect the DI for the bottom part to be higher based on DP's performance in the chordal disaggregation experiment; rhythmic errors were the main factor in the low DI that he achieved.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Average
TOP WP		0.07	0.07	0.18	0.31	0.10	0.14	0.21	0.19	0.31	0.27	0.22	0.28	0.26	0.20
INNER WP		0.06	0.07	0.15	0.29	0.10	0.20	0.27	0.24	0.35	0.27	0.25	0.28	0.28	0.22
BOTTOM WP		0.09	0.09	0.10	0.36	0.13	0.19	0.16	0.24	0.31	0.22	0.21	0.29	0.35	0.21
TOP BT	0.57	0.59	0.61	0.58	0.63	0.66	0.66	0.61	0.64	0.67	0.62	0.61	0.62	0.67	0.62
INNER BT	0.51	0.53	0.58	0.52	0.58	0.57	0.63	0.60	0.64	0.63	0.67	0.64	0.64	0.68	0.60
BOTTOM BT	0.58	0.63	0.69	0.59	0.61	0.63	0.60	0.69	0.64	0.67	0.71	0.68	0.73	0.74	0.66

Fig. 4.24 WP and BT for top, inner and bottom parts.

4.6.7 Analysis of the top, inner and bottom parts for pitch and rhythm in WP and BT

Looking at the derivation indices pertaining to the top part of the WP trials shown in Figure 4.25, one can see that DP is more successful in recalling rhythm only twice (in the first and in the second trial). The top part improves 44% more in the domain of pitch than rhythm.

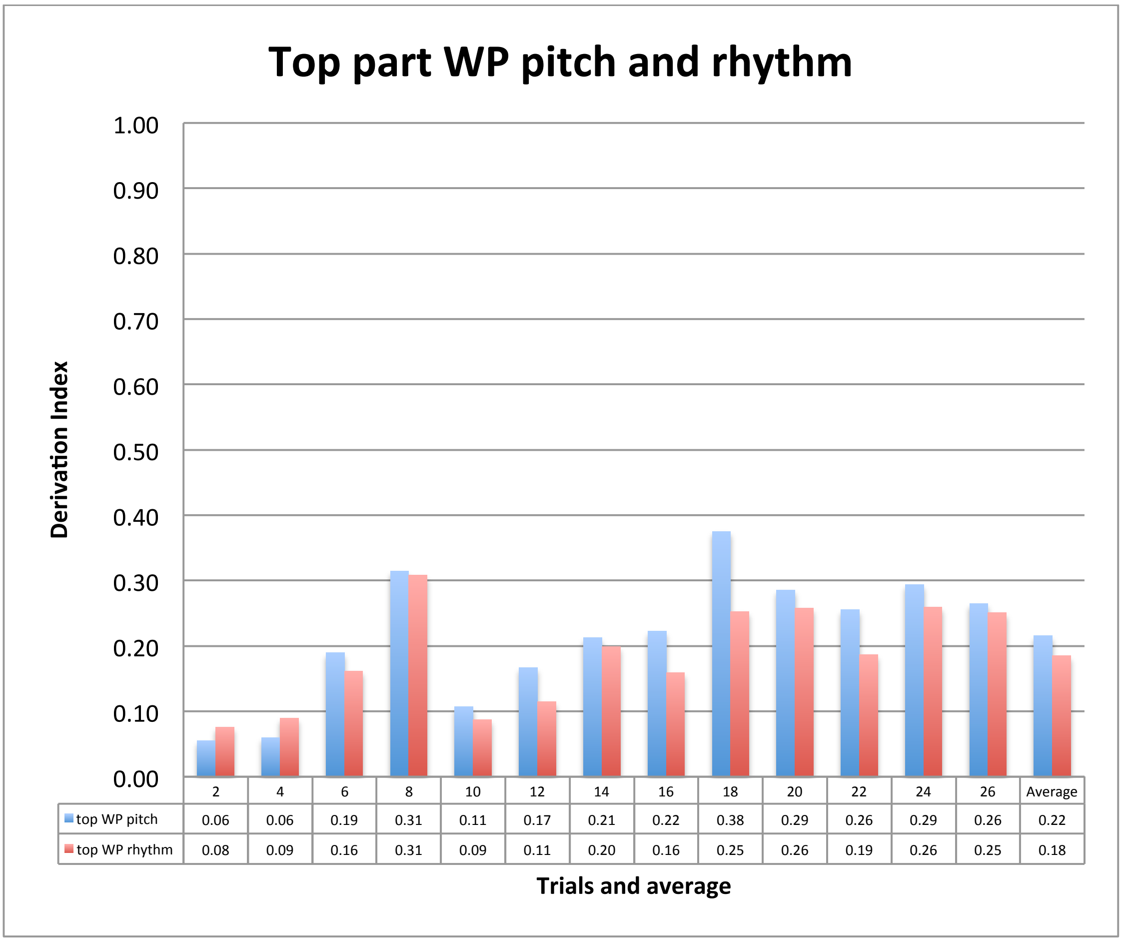


Fig. 4.25 Top part WP, for pitch and rhythm.

With regard to the inner part, the DIs for pitch and rhythm were equal for trials 2 and 4. In all other trials DP consistently achieves a higher DI for the pitch compared to the rhythm (ranging between 2% and 57% higher, with an average of 22%, see Figure 4.26). In both conditions the improvement in the inner part was probably due to a lack of systematic mistakes.

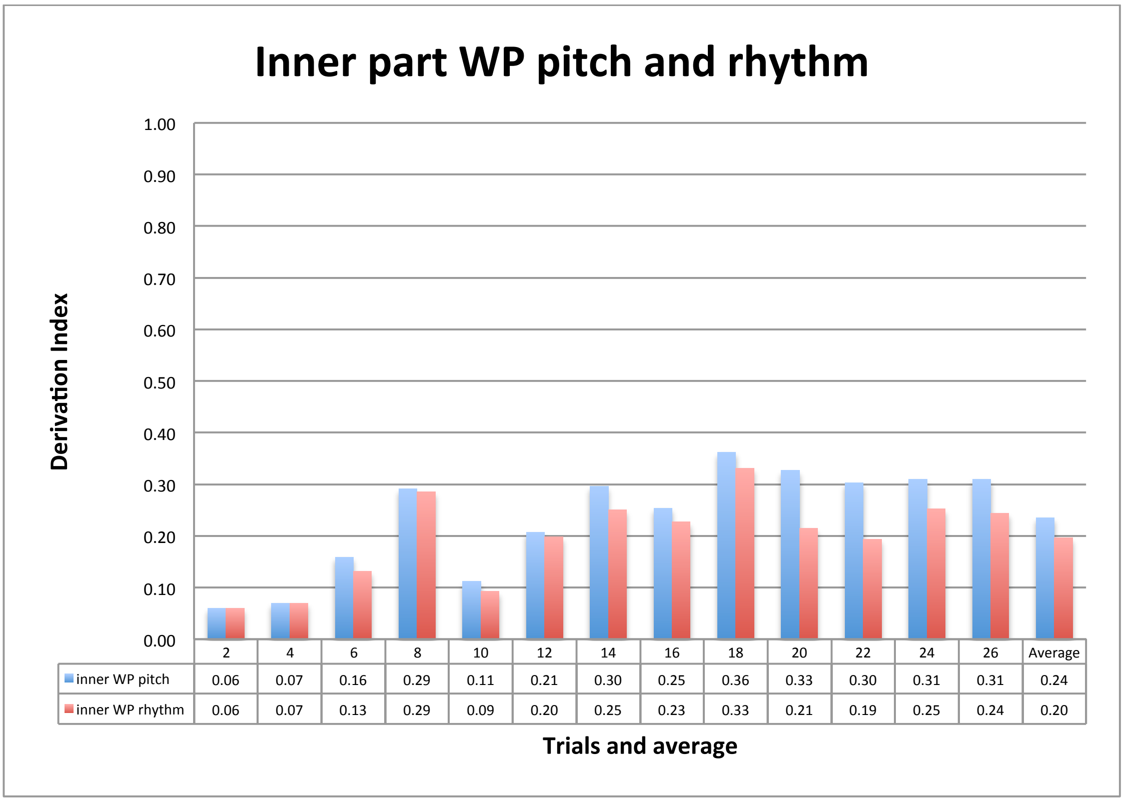


Fig. 4.26 Inner part WP, for pitch and rhythm.

In the bottom part the DI for pitch in WP is again consistently (and increasingly) higher than for rhythm (see Figure 4.27), on account of the proportion of additional notes (of incorrect duration) varying more in WP. The ratio between the DIs for pitch and rhythm is between 25% and 420% higher, with an average of 94%. The ratio between the two DIs is more variable than for BT (see Figure 4.32), perhaps due to the higher proportion of added notes.

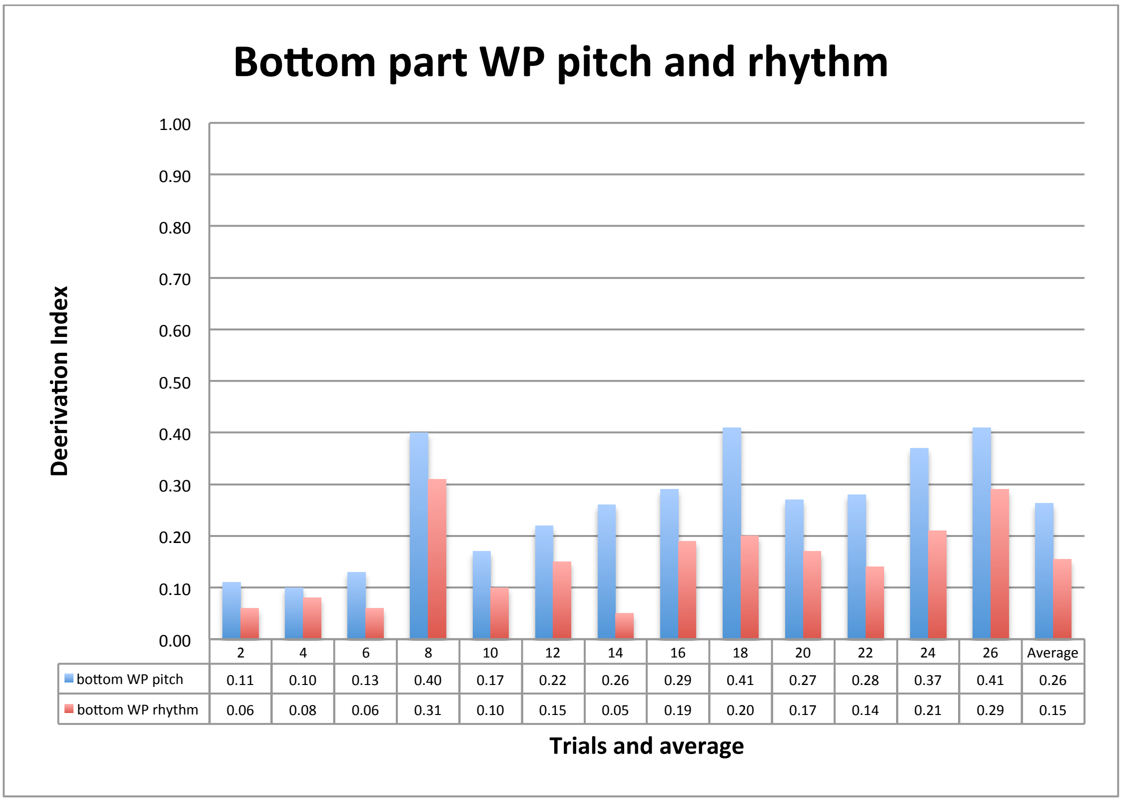


Fig. 4.27 Bottom part WP, for pitch and rhythm.

Moving to the analysis of BT, the overall scores are much higher compared to WP (see Figure 4.28 for average scores).

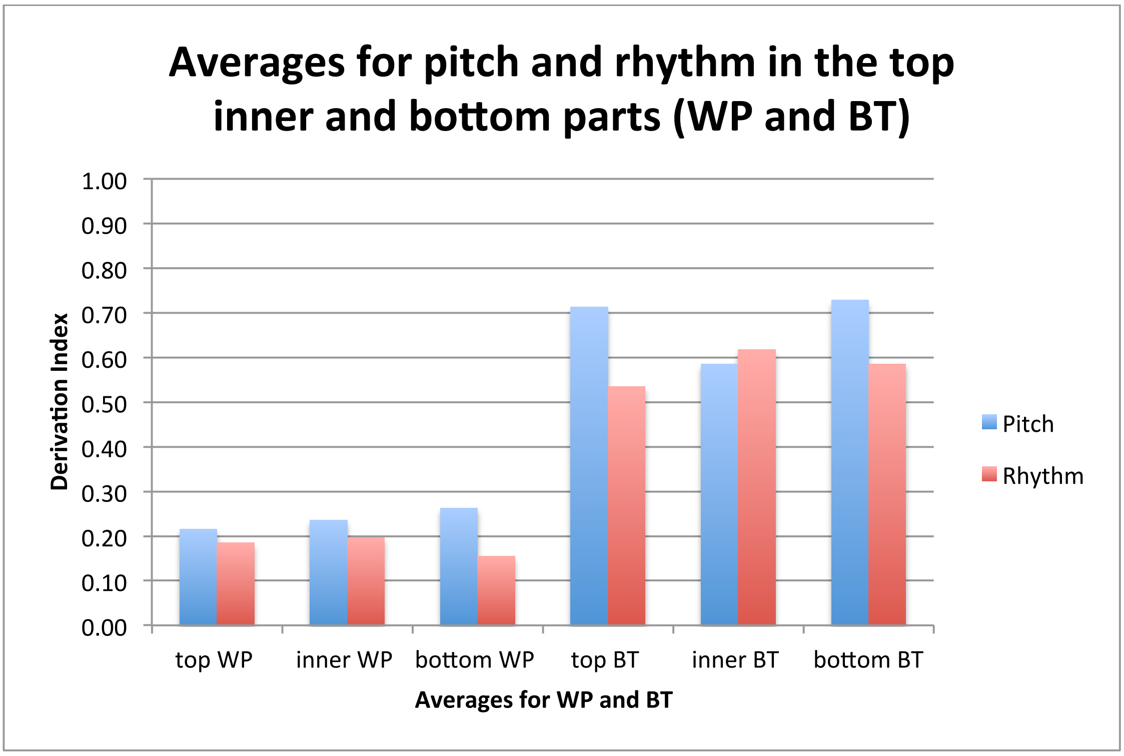


Fig. 4.28 Averages for pitch and rhythm in the top, inner and bottom parts.

Concerning the top part, (see Figure 4.29) the DI for pitch is again consistently (and increasingly) higher than that for rhythm, increasing by 0.07 DI for each trial, compared to rhythm that is more or less static.

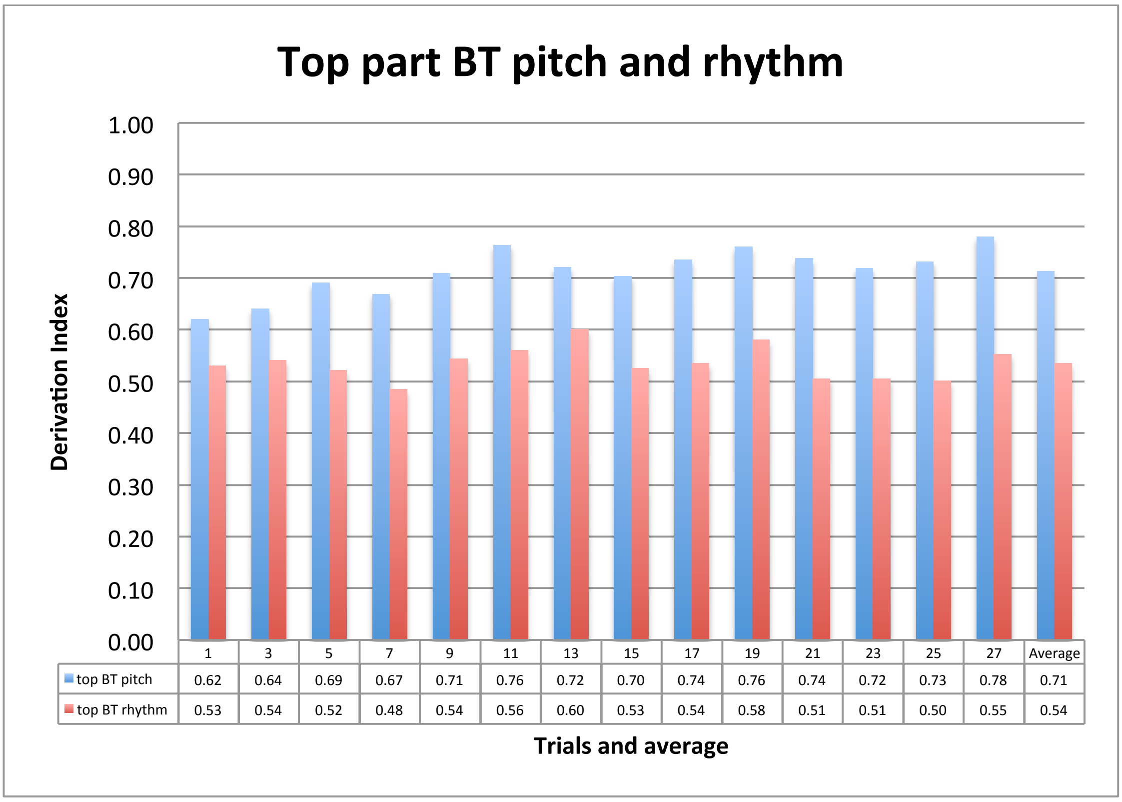


Fig. 4.29 Top part BT, for pitch and rhythm.

Regarding the inner part of BT trials (see Figure 4.30), this is the first and the only time in which the rhythm is consistently higher than the pitch. This can explained on account of systematic errors such as those now described. For example, in trial 13, bar 2, (see Figure 4.31) DP transposes the semitone interval from B natural–C to C–D♭, making it more harmonically conventional. In the next bar (3) DP borrows the material belonging to the to bar (2). Since the pitch pattern is different, this results in a lower DI in this domain. However, the rhythm is very similar in both bars – hence the rhythmic DI is largely unaffected.

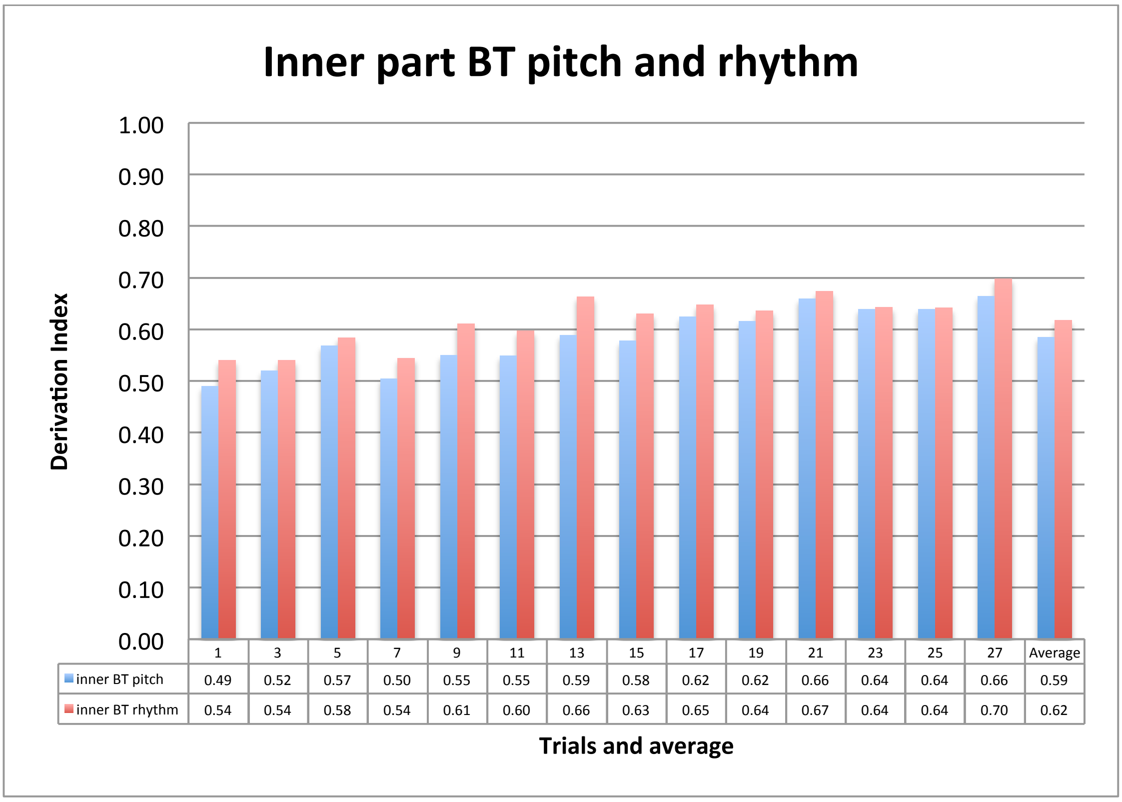
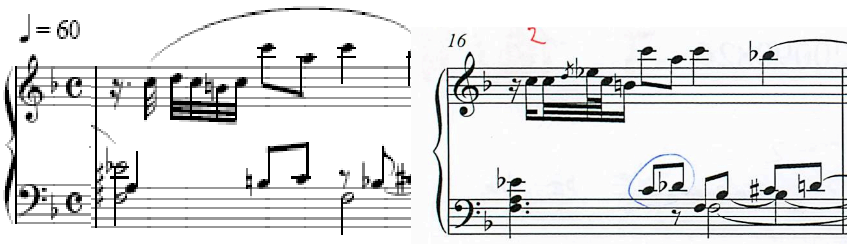


Fig. 4.30 Inner part BT, for pitch and rhythm.

Stimulus **Response**



Analysis of the response

Trial 13, bar 2, inner part, BT

Fig. 4.31 Example of pitch errors in the inner parts.

Looking at the derivation indices pertaining to the bottom part of the BT trials shown in Figure 4.32, one can see that DP consistently scores higher for pitch than for rhythm (ranging between 10% and 43% higher, with an average of 25%). Again this is likely to be because of the additions that DP made, since as long as the correct pitch was present, it would be regarded as being derived from the stimulus, irrespective of any additional pitches that may follow. However, in the domain of rhythm, additional durations (for example) would impact on one another, since an additional note would be likely to ‘borrow’ some of the duration from the one preceding. DP tended to repeat the same errors for pitch and rhythm as in the WP trials. The ratio between the two scores is less variable than for WP (see Figures 4.27 and 4.32).

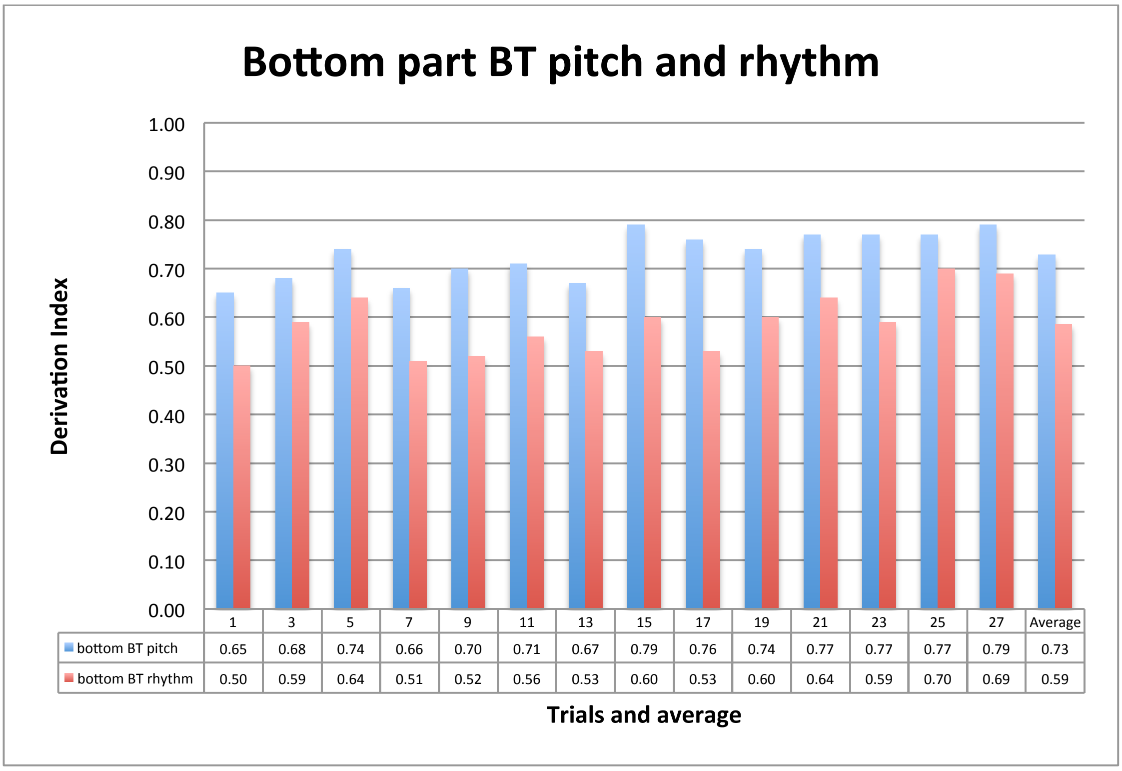


Fig. 4.32 Bottom part BT, for pitch and rhythm.

In BT, any increase in scores between the trials was largely due to improvement of the inner and bottom parts in relation to both pitch and rhythm (see Figure 4.33). It appears that the systematic errors in the top part (see Tables 4.19, 4.20 and 4.21) were more resistant to subsequent correction.

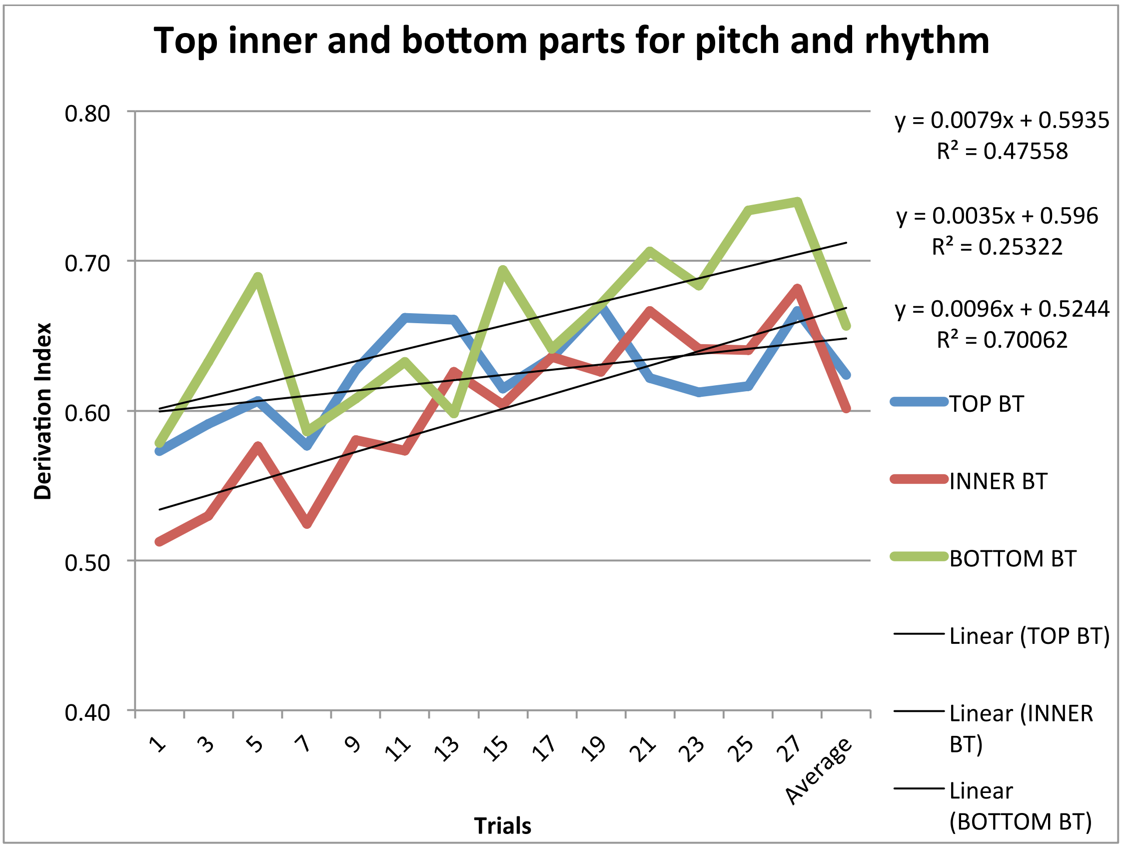


Fig. 4.33 Top inner and bottom parts for both pitch and rhythm across all BT trials.

4.6.8 Analysis of the additions and omissions in WP

Next there follows a consideration of the number of additions and omissions that DP made during WP trials. In these trials DP omitted a number of bars from the stimulus (see Table 4.3) indicated in the following Tables with 'np' meaning not played.

The Tables that follow (from 4.6 to 4.15) list in the first column the number of musical events that are present in the stimulus (S) and in the response (R) in the top, inner and bottom parts, during a sample of trials (2, 6, 12, 18 and 24 for WP). The Tables also display the number of additions and omissions per trial.

Table 4.6 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for WP (trial 2).

Bars	# events top parts	# added	# omitted	# events inner parts	# added	# omitted	# events bottom parts	# added	# omitted
1S	5	0	0	6	7	0	3	0	0
1R	**5**			**13**			**3**		
2S	9	np		7			2		
2R	**9**			**7**			**2**		
3S	5	0	0	10	2	0	2	2	0
3R	**5**			**12**			**4**		
4S	9	np		8			2		
4R	**9**			**8**			**2**		
5S	5	np		6			2		
5R	**5**			**6**			**2**		
6S	9	np		7			2		
6R	**9**			**7**			**2**		
7S	5	np		6			2		
7R	**5**			**6**			**2**		
8S	10	np		7			2		
8R	**10**			**7**			**2**		
9S	6	np		6			3		
9R	**6**			**6**			**3**		
10S	9	np		7			2		
10R	**9**			**7**			**2**		
11S	5	np		10			2		
11R	**5**			**10**			**2**		
12S	9	np		8			2		
12R	**9**			**8**			**2**		
13S	5	np		6			2		
13R	**5**			**6**			**2**		
14S	9	np		7			2		
14R	**9**			**7**			**2**		
15S	6	np		7			2		
15R	**6**			**7**			**2**		
16S	9	np		8			2		
16R	**9**			**8**			**2**		
17S	7	np		8			4		
17R	**7**			**8**			**4**		
18S	6	0	0	10	11	0	3	2	0
18R	**6**			**21**			**5**		
19S	1	3	0	5	12	0	3	1	0
19R	**4**			**17**			**4**		
Total additions and omissions		**3**	**0**		**32**	**0**		**5**	**0**

Table 4.7 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for WP (trial 6).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**# events bottom parts**	# added	# omitted
1S	5	0	0	6	2	0	3	2	0
1R	**5**			**8**			**5**		
2S	9	0	0	7	1	0	2	4	0
2R	**9**			**8**			**6**		
3S	5	np		10			2		
3R	**5**			**10**			**2**		
4S	9	np		8			2		
4R	**9**			**8**			**2**		
5S	5	np		6			2		
5R	**5**			**6**			**2**		
6S	9	np		7			2		
6R	**9**			**7**			**2**		
7S	5	np		6			2		
7R	**5**			**6**			**2**		
8S	10	np		7			2		
8R	**10**			**7**			**2**		
9S	6	0	0	6	5	0	3	0	0
9R	**6**			**11**			**3**		
10S	9	np		7			2		
10R	**9**			**7**			**2**		
11S	5	1	0	10	7	0	2	1	0
11R	**6**			**17**			**3**		
12S	9	np		8			2		
12R	**9**			**8**			**2**		
13S	5	np		6			2		
13R	**5**			**6**			**2**		
14S	9	np		7			2		
14R	**9**			**7**			**2**		
15S	6	np		7			2		
15R	**6**			**7**			**2**		
16S	9	1	0	8	5	0	2	2	0
16R	**10**			**13**			**4**		
17S	7	2	0	8	1	0	4	3	0
17R	**9**			**9**			**7**		
18S	6	np		10			3		
18R	**6**			**10**			**3**		
19S	1	19	0	5	15	0	3	0	0
19R	**20**			**20**			**3**		
Total additions and omissions		**23**	**0**		**36**	**0**		**12**	**0**

Table 4.8 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for WP (trial 12).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**# events bottom parts**	# added	# omitted
1S	5	2	0	6	5	0	3	2	0
1R	**7**			**11**			**5**		
2S	9	0	0	7	0	0	2	0	0
2R	**9**			**7**			**2**		
3S	5	6	0	10	0	0	2	0	0
3R	**11**			**10**			**2**		
4S	9	0	0	8	0	0	2	1	0
4R	**9**			**8**			**3**		
5S	5	np		6			2		
5R	**5**			**6**			**2**		
6S	9	np		7			2		
6R	**9**			**7**			**2**		
7S	5	np		6			2		
7R	**5**			**6**			**2**		
8S	10	np		7			2		
8R	**10**			**7**			**2**		
9S	6	np		6			3		
9R	**6**			**6**			**3**		
10S	9	0	0	7	0	0	2	0	0
10R	**9**			**7**			**2**		
11S	5	5	0	10	0	0	2	0	0
11R	**10**			**10**			**2**		
12S	9	np		8			2		
12R	**9**			**8**			**2**		
13S	5	np		6			2		
13R	**5**			**6**			**2**		
14S	9	np		7			2		
14R	**9**			**7**			**2**		
15S	6	np		7			2		
15R	**6**			**7**			**2**		
16S	9	np		8			2		
16R	**9**			**8**			**2**		
17S	7	np		8			4		
17R	**7**			**8**			**4**		
18S	6	2	0	10	0	0	3	0	0
18R	**8**			**10**			**3**		
19S	1	0	0	5	0	0	3	0	0
19R	**1**			**5**			**3**		
Total additions and omissions		**15**	**0**		**5**	**0**		**3**	**0**

Table 4.9 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for WP (trial 18).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**# events bottom parts**	# added	# omitted
1S	5	2	0	6	2	0	3	5	0
1R	**7**			**8**			**8**		
2S	9	1	0	7	0	0	2	0	0
2R	**10**			**7**			**2**		
3S	5	5	0	10	0	0	2	0	0
3R	**10**			**10**			**2**		
4S	9	1	0	8	2	0	2	0	0
4R	**10**			**10**			**2**		
5S	5	0	0	6	0	0	2	0	0
5R	**5**			**6**			**2**		
6S	9	1	0	7	0	0	2	0	0
6R	**10**			**7**			**2**		
7S	5	0	0	6	1	0	2	0	0
7R	**5**			**7**			**2**		
8S	10	1	0	7	1	0	2	0	0
8R	**11**			**8**			**2**		
9S	6	np		6			3		
9R	**6**			**6**			**3**		
10S	9	np		7			2		
10R	**9**			**7**			**2**		
11S	5	np		10			2		
11R	**5**			**10**			**2**		
12S	9	np		8			2		
12R	**9**			**8**			**2**		
13S	5	np		6			2		
13R	**5**			**6**			**2**		
14S	9	np		7			2		
14R	**9**			**7**			**2**		
15S	6	np		7			2		
15R	**6**			**7**			**2**		
16S	9	np		8			2		
16R	**9**			**8**			**2**		
17S	7	1	0	8	2	0	4	2	0
17R	**8**			**10**			**6**		
18S	6	0	0	10	5	0	3	1	0
18R	**6**			**15**			**4**		
19S	1	2	0	5	7	0	3	0	0
19R	**3**			**12**			**3**		
Total additions and omissions		**14**	**0**		**20**	**0**		**8**	**0**

Table 4.10 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for WP (trial 24).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**# events bottom parts**	# added	# omitted
1S	5	np		6			3		
1R	**5**			**6**			**3**		
2S	9	np		7			2		
2R	**9**			**7**			**2**		
3S	5	np		10			2		
3R	**5**			**10**			**2**		
4S	9	np		8			2		
4R	**9**			**8**			**2**		
5S	5	np		6			2		
5R	**5**			**6**			**2**		
6S	9	np		7			2		
6R	**9**			**7**			**2**		
7S	5	np		6			2		
7R	**5**			**6**			**2**		
8S	10	np		7			2		
8R	**10**			**7**			**2**		
9S	6	1	0	6	4	0	3	3	0
9R	**7**			**10**			**6**		
10S	9	0	0	7	0	0	2	0	0
10R	**9**			**7**			**2**		
11S	5	5	0	10	0	0	2	0	0
11R	**10**			**10**			**2**		
12S	9	0	0	8	0	0	2	1	0
12R	**9**			**8**			**3**		
13S	5	0	0	6	1	0	2	0	0
13R	**5**			**7**			**2**		
14S	9	1	0	7	0	0	2	0	0
14R	**10**			**7**			**2**		
15S	6	3	0	7	0	0	2	0	0
15R	**9**			**7**			**2**		
16S	9	np		8			2		
16R	**9**			**8**			**2**		
17S	7	0	0	8	2	0	4	2	0
17R	**7**			**10**			**6**		
18S	6	0	0	10	1	0	3	2	0
18R	**6**			**11**			**5**		
19S	1	0	0	5	2	0	3	0	0
19R	**1**			**7**			**3**		
Total additions and omissions		**10**	**0**		**10**	**0**		**8**	**0**

Table 4.11 and Figure 4.34 display the total number of additions, made by DP during WP trials (2, 6, 12, 18 and 24); no omissions were made during these trials.

Table 4.11 Total number of additions of the top, inner and bottom parts throughout WP trials.

Total additions	Top	Inner	Bottom
Trial 2	3	32	5
Trial 6	23	36	12
Trial 12	15	5	3
Trial 18	14	20	8
Trial 24	10	10	8
Mean	**13**	**20.6**	**7.2**

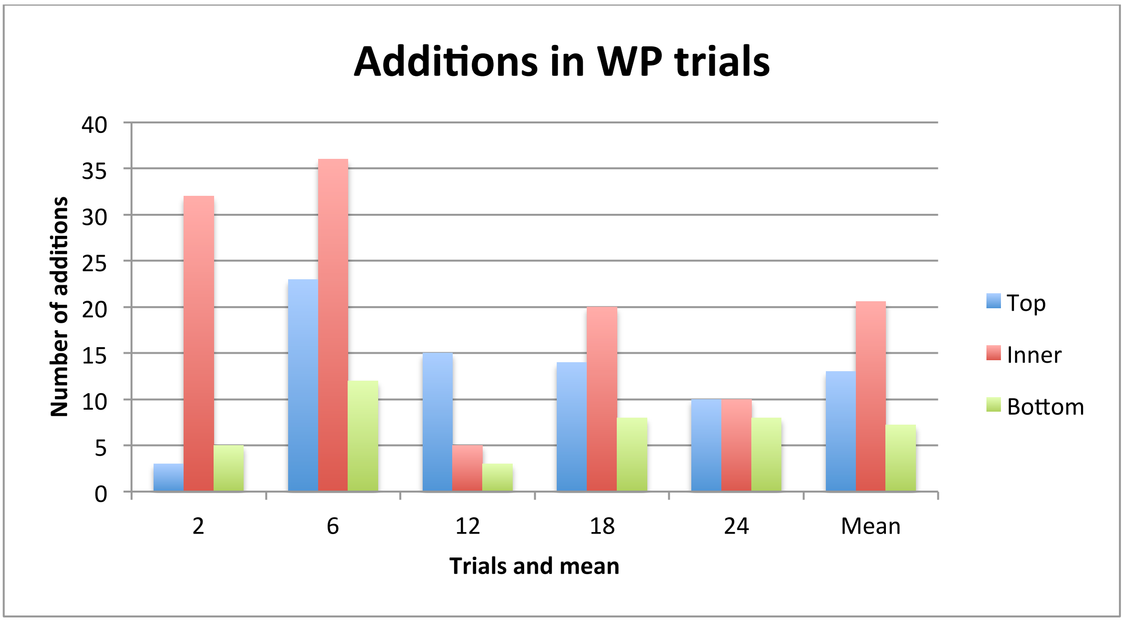


Fig. 4.34 Additions in WP trials.

Table 4.11 and Figure 4.34 show that DP consistently added notes. No omissions were made. In four trials out of five he made a greater number of additions in the inner part, followed by the top and the bottom parts.

4.6.9 Analysis of the additions and omissions in BT and comparison with WP

Tables 4.12 to 4.16 display the additions and omissions during the BT trials (1, 7, 13, 19 and 25).

Table 4.12 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for BT (trial 1).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**#events bottom parts**	# added	# omitted
1S	5	0	0	6	1	0	3	0	0
1R	**5**			**7**			**3**		
2S	9	1	0	7	0	0	2	0	0
2R	**10**			**7**			**2**		
3S	5	0	0	10	0	0	2	0	0
3R	**5**			**10**			**2**		
4S	9	3	0	8	0	0	2	0	0
4R	**12**			**8**			**2**		
5S	5	4	0	6	1	0	2	0	0
5R	**9**			**7**			**2**		
6S	9	0	0	7	0	0	2	0	0
6R	**9**			**7**			**2**		
7S	5	0	0	6	0	0	2	0	0
7R	**5**			**6**			**2**		
8S	10	1	0	7	0	1	2	0	0
8R	**11**			**6**			**2**		
9S	6	0	0	6	0	0	3	2	0
9R	**6**			**6**			**5**		
10S	9	2	0	7	0	0	2	0	0
10R	**11**			**7**			**2**		
11S	5	5	0	10	0	0	2	0	0
11R	**10**			**10**			**2**		
12S	9	1	0	8	0	0	2	0	0
12R	**10**			**8**			**2**		
13S	5	0	0	6	2	0	2	0	0
13R	**5**			**8**			**2**		
14S	9	1	0	7	1	0	2	0	0
14R	**10**			**8**			**2**		
15S	6	0	0	7	1	0	2	0	0
15R	**6**			**8**			**2**		
16S	9	1	0	8	0	0	2	0	0
16R	**10**			**8**			**2**		
17S	7	0	0	8	1	0	4	0	0
17R	**7**			**9**			**4**		
18S	6	1	0	10	1	0	3	3	0
18R	**7**			**11**			**6**		
19S	1	0	0	5	1	0	3	0	0
19R	**1**			**6**			**3**		
Total additions and omissions		**20**	**0**		**9**	**1**		**5**	**0**

Table 4.13 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for BT (trial 7).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**# events bottom parts**	# added	# omitted
1S	5	0	0	6	1	0	3	0	0
1R	**5**			**7**			**3**		
2S	9	0	0	7	1	0	2	0	0
2R	**9**			**8**			**2**		
3S	5	0	0	10	0	0	2	0	0
3R	**5**			**10**			**2**		
4S	9	1	0	8	0	0	2	0	0
4R	**10**			**8**			**2**		
5S	5	0	0	6	0	0	2	0	0
5R	**5**			**6**			**2**		
6S	9	1	0	7	0	0	2	0	0
6R	**10**			**7**			**2**		
7S	5	0	0	6	0	0	2	0	0
7R	**5**			**6**			**2**		
8S	10	1	0	7	0	0	2	0	0
8R	**11**			**7**			**2**		
9S	6	0	0	6	0	0	3	2	0
9R	**6**			**6**			**5**		
10S	9	3	0	7	0	0	2	0	0
10R	**12**			**7**			**2**		
11S	5	5	0	10	0	0	2	0	0
11R	**10**			**10**			**2**		
12S	9	1	0	8	0	0	2	0	0
12R	**10**			**8**			**2**		
13S	5	0	0	6	0	0	2	0	0
13R	**5**			**6**			**2**		
14S	9	2	0	7	0	0	2	0	0
14R	**11**			**7**			**2**		
15S	6	0	0	7	0	0	2	0	0
15R	**6**			**7**			**2**		
16S	9	1	0	8	0	0	2	0	0
16R	**10**			**8**			**2**		
17S	7	0	0	8	4	0	4	0	0
17R	**7**			**12**			**4**		
18S	6	1	0	10	4	0	3	3	0
18R	**7**			**14**			**6**		
19S	1	2	0	5	3	0	3	0	0
19R	**3**			**8**			**3**		
Total additions and omissions		**18**	**0**		**13**	**0**		**5**	**0**

Table 4.14 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for BT (trial 13).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**# events bottom parts**	# added	# omitted
1S	5	0	0	6	1	0	3	2	0
1R	**5**			**7**			**5**		
2S	9	1	0	7	0	0	2	0	0
2R	**10**			**7**			**2**		
3S	5	0	0	10	1	0	2	0	0
3R	**5**			**11**			**2**		
4S	9	0	0	8	0	2	2	0	0
4R	**9**			**10**			**2**		
5S	5	0	0	6	0	0	2	0	0
5R	**5**			**6**			**2**		
6S	9	1	0	7	0	0	2	0	0
6R	**10**			**7**			**2**		
7S	5	0	0	6	1	0	2	0	0
7R	**5**			**7**			**2**		
8S	10	0	0	7	0	0	2	0	0
8R	**10**			**7**			**2**		
9S	6	0	0	6	1	0	3	0	0
9R	**6**			**7**			**3**		
10S	9	0	0	7	0	0	2	1	0
10R	**9**			**7**			**3**		
11S	5	4	0	10	1	0	2	0	0
11R	**9**			**11**			**2**		
12S	9	1	0	8	1	0	2	1	0
12R	**10**			**9**			**3**		
13S	5	0	0	6	0	0	2	0	0
13R	**5**			**6**			**2**		
14S	9	1	0	7	0	0	2	0	0
14R	**10**			**7**			**2**		
15S	6	0	0	7	0	0	2	0	0
15R	**6**			**7**			**2**		
16S	9	0	0	8	1	0	2	0	0
16R	**9**			**9**			**2**		
17S	7	0	0	8	0	0	4	0	0
17R	**7**			**8**			**4**		
18S	6	0	0	10	0	0	3	0	0
18R	**6**			**10**			**3**		
19S	1	0	0	5	1	0	3	0	0
19R	**1**			**6**			**3**		
Total additions and omissions		**8**	**0**		**8**	**0**		**4**	**0**

Table 4.15 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for BT (trial 19).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**# events bottom parts**	# added	# omitted
1S	5	0	0	6	1	0	3	0	0
1R	**5**			**7**			**3**		
2S	9	0	0	7	0	0	2	0	0
2R	**9**			**7**			**2**		
3S	5	0	0	10	0	0	2	0	0
3R	**5**			**10**			**2**		
4S	9	0	0	8	0	0	2	0	0
4R	**9**			**8**			**2**		
5S	5	0	0	6	0	0	2	0	0
5R	**5**			**6**			**2**		
6S	9	1	0	7	0	0	2	0	0
6R	**10**			**7**			**2**		
7S	5	0	0	6	1	0	2	0	0
7R	**5**			**7**			**2**		
8S	10	1	0	7	2	0	2	0	0
8R	**11**			**9**			**2**		
9S	6	0	0	6	1	0	3	0	0
9R	**6**			**7**			**3**		
10S	9	0	0	7	0	0	2	0	0
10R	**9**			**7**			**2**		
11S	5	0	0	10	1	0	2	0	0
11R	**5**			**11**			**2**		
12S	9	1	0	8	2	0	2	0	0
12R	**10**			**10**			**2**		
13S	5	0	0	6	0	0	2	0	0
13R	**5**			**6**			**2**		
14S	9	1	0	7	0	0	2	0	0
14R	**10**			**7**			**2**		
15S	6	0	0	7	0	0	2	0	0
15R	**6**			**7**			**2**		
16S	9	1	0	8	0	0	2	0	0
16R	**10**			**8**			**2**		
17S	7	0	0	8	0	0	4	0	0
17R	**7**			**8**			**4**		
18S	6	0	0	10	1	0	3	0	0
18R	**6**			**11**			**3**		
19S	1	0	0	5	1	0	3	0	0
19R	**1**			**6**			**3**		
Total additions and omissions		**5**	**0**		**10**	**0**		**0**	**0**

Table 4.16 The number of events in the stimulus and in the response and the total number of additions and omissions pertaining to the top, inner and bottom parts for BT (trial 25).

Bars	**# events top parts**	# added	# omitted	**# events inner parts**	# added	# omitted	**# events bottom parts**	# added	# omitted
1S	5	0	0	6	1	0	3	0	0
1R	**5**			**7**			**3**		
2S	9	0	0	7	0	0	2	0	0
2R	**9**			**7**			**2**		
3S	5	0	0	10	0	0	2	0	0
3R	**5**			**10**			**2**		
4S	9	1	0	8	0	0	2	0	0
4R	**10**			**8**			**2**		
5S	5	0	0	6	0	0	2	0	0
5R	**5**			**6**			**2**		
6S	9	1	0	7	0	0	2	0	0
6R	**10**			**7**			**2**		
7S	5	0	0	6	1	0	2	0	0
7R	**5**			**7**			**2**		
8S	10	1	0	7	0	0	2	0	0
8R	**11**			**7**			**2**		
9S	6	0	0	6	1	0	3	0	0
9R	**6**			**7**			**3**		
10S	9	1	0	7	0	0	2	0	0
10R	**10**			**7**			**2**		
11S	5	4	0	10	0	0	2	0	0
11R	**9**			**10**			**2**		
12S	9	1	0	8	0	0	2	0	0
12R	**10**			**8**			**2**		
13S	5	0	0	6	0	0	2	0	0
13R	**5**			**6**			**2**		
14S	9	1	0	7	0	0	2	0	0
14R	**10**			**7**			**2**		
15S	6	0	0	7	1	0	2	0	0
15R	**6**			**8**			**2**		
16S	9	1	0	8	1	0	2	0	0
16R	**10**			**9**			**2**		
17S	7	0	0	8	0	0	4	0	0
17R	**7**			**8**			**4**		
18S	6	0	0	10	0	0	3	0	0
18R	**6**			**10**			**3**		
19S	1	2	0	5	3	0	3	0	0
19R	**3**			**8**			**3**		
Total additions and omissions		**13**	**0**		**8**	**0**		**0**	**0**

Tables 4.17 and 4.18 and Figure 4.35 display the total number of additions and omissions made by DP in BT trials (1, 7, 13, 19 and 25).

Table 4.17 Total number of additions of the top, inner and bottom parts throughout BT trials.

Total additions	Top	Inner	Bottom
Trial 1	20	9	5
Trial 7	18	13	5
Trial 13	8	8	4
Trial 19	5	10	0
Trial 25	13	8	0
Mean	**12.8**	**9.6**	**2.8**

Table 4.18 Total number of omissions of the top, inner and bottom parts throughout trials.

Total omissions	Top	Inner	Bottom
Trial 1	0	1	0
Trial 7	0	0	0
Trial 13	0	0	0
Trial 19	0	0	0
Trial 25	0	0	0
Mean	**0**	**0.2**	**0**

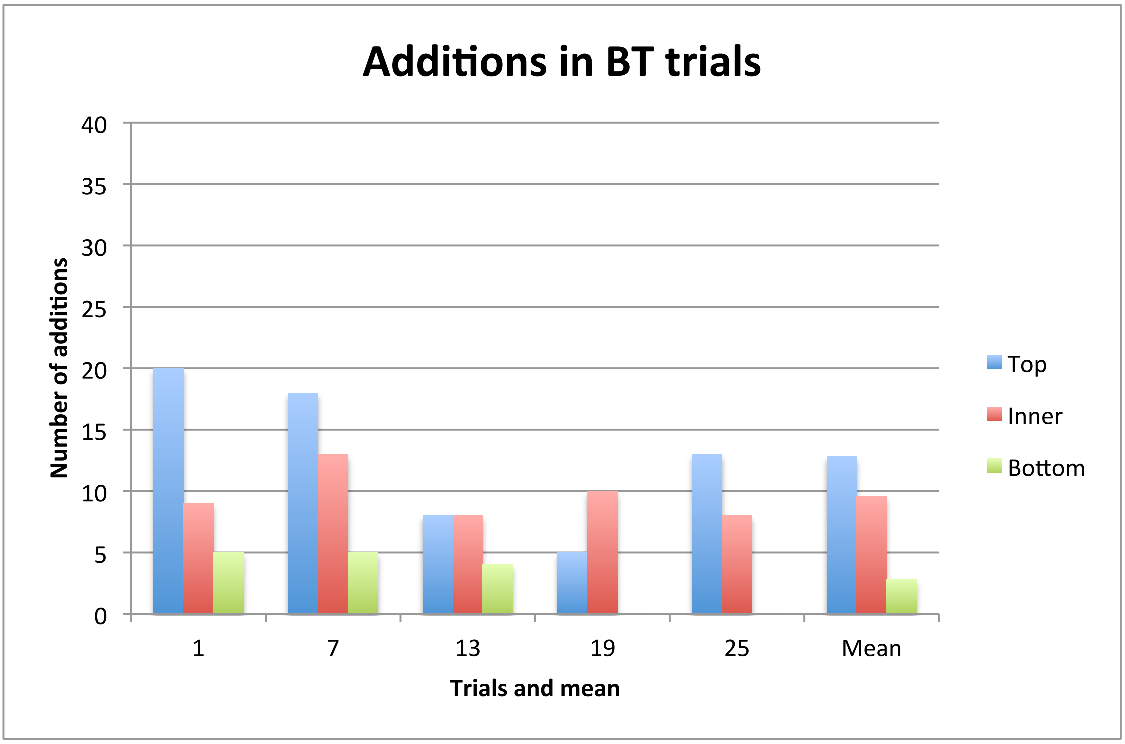


Fig. 4.35 Additions in BT trials.

Tables 4.17 and 4.18 and Figure 4.35 show that DP consistently added notes, but only once omitted one. This shows that he was able to hear and reproduce everything that was in the stimulus, but appeared to have a preference for fuller or more complex musical textures. This is in line with the findings of the *Chromatic Blues* study (Ockelford, 2012), which will be discussed in Chapter 6.

Comparing additions and omissions, DP made more additions in WP than in BT (see Figure 4.36). This could have been due to the different nature of the task: BT was easier, as DP had to replicate each bar separately after hearing it, whereas in WP, there was more room for his 'creative reconstruction' of the stimulus from long term memory.

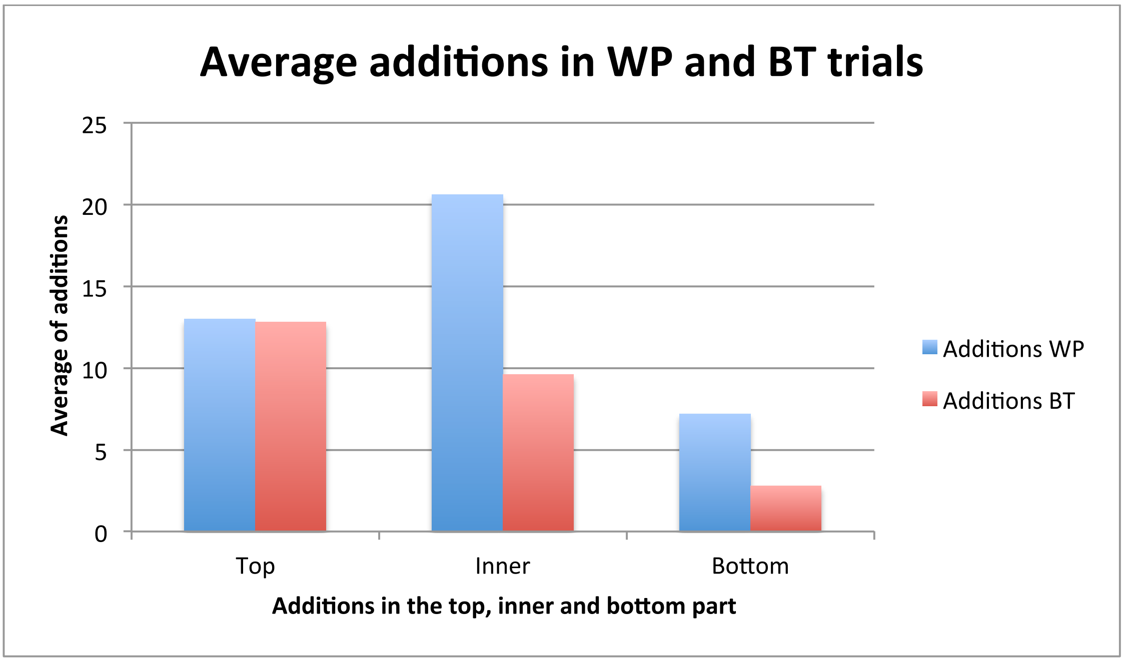


Fig. 4.36 Average of additions in WP and BT trials.

4.6.10 General analysis of errors for WP and BT

Overall, it seems that, following an initial period of learning, DP's recall in WP reached a plateau: looking at the transcriptions it is clear that as the trials progressed DP had a tendency to fix certain melodic or rhythmic elements in his mind, and to repeat them irrespective of whether they were right or wrong – that is, some errors became systematic.

The last three bars of the stimulus were always played. Besides the coda, he frequently played the first 5 bars of section A (1–5) or (9–13) and sometimes section B1 or B2 (see Figure 4.1), but in general not the whole of it, and with a greater tendency to make mistakes. It appears that DP did not correctly internalise the structure of the musical piece (which, as noted above, was $A_{1.1}$ $B_{1.1}$ $A_{2.1}$ $B_{2.2}$ C). We can assume this, because in most of the trials he started playing from $A_{2.1}$ until the end of the piece (excluding the first part), so the fact the structure was repeated did not help him. In the B section DP made more errors, however less systematically than in the A section, where his performance was very similar his performance in BT. To summarise: DP demonstrated that he learned the A section and the coda (C); however he was only able to recall a portion of section B. Generally DP repeated the same errors throughout the trials, but not necessarily in the same bars (this was possible since many of the bars were similar in construction).

In places, the stimulus was designed deliberately to be stylistically unusual. In these places, DP tended to alter what he heard to make it more conventional. For example, DP modified parts of the harmonic structure in trial 2, bar 2 (WP), by modulating to G minor (the subdominant of D minor) in preference to the move to the submediant (B♭ major) that is found in the stimulus at this point (see Figure 4.37).

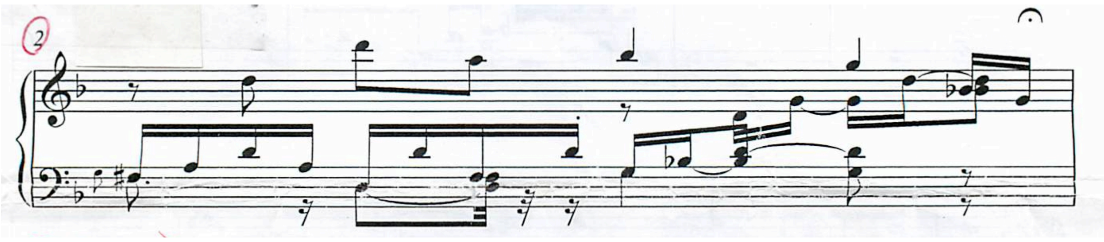


Fig. 4.37 Trial 2, bar 2, WP.

Some errors were the result of DP's tendency to improvise and to embellish the stimulus; for example, as we have seen above, he often played a quintuplet instead of a quadruplet, and repeated certain notes. Other, 'random' errors occurred only once or twice overall and appear to be the consequence of (for example) finger slips. Bars that were played correctly tended to remain accurate in subsequent trials. Other errors involved musical fragments played in the wrong octave – a not uncommon error for AP possessors.

However, analysis of the results suggests that the majority of DP's errors were due to systematic changes. For example, in the domain or rhythm, in some cases the duration was wrong, while the inter-onset interval was correct. Conversely, on other occasions, when the lengths of the notes were incorrect (particularly where they were too long), the inter-onset intervals could also be affected. These types of errors were found both in WP and BT, showing the power of his memory of the immediate stimulus. Examples of the systematic mistakes mentioned above are shown in Figures 4.38 and 4.39. During the analysis similar errors were found which affect the DIs substantially.

Trial 2, bar 19, inner part, WP

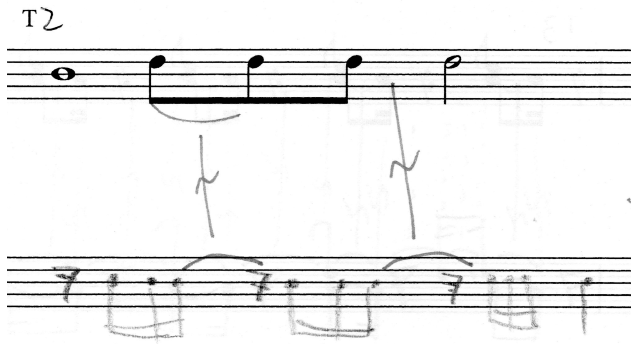


Fig. 4.38 Variation of note length in WP.

Trial 3, bar 19, inner part, BT

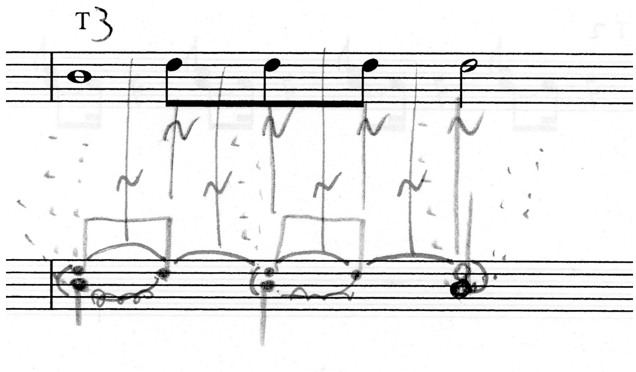


Fig. 4.39 Variation of note length in BT.

There are two other types of error mentioned above (see Figures 4.15 and 4.16). The first is rhythmic, in which DP substituted a quadruplet with a quintuplet (this considerably affects the rhythmic results for half of the bars in the top part) that were common to WP and BT (*cf.* 4.6.3, Figures 4.15 and 4.16). This seems less likely to be a perceptual error than DP consciously and purposely embellishing what he heard without concern for the accuracy of the stimulus.

The source of some errors may have been DP’s desire to create a coherent narrative out of the separate fragments he could remember. Hence changes were made to make the separate bars fit together in a way that made musical sense (*cf.* Ockelford, 2012). One example of this is the transposition of a melody fragment by a semitone or tone (higher or lower), maintaining to some extent, but not completely, the intervals (see Tables 4.19, 4.20 and 4.21). Figure 4.40, 4.41 and 4.42 illustrate a correct interval in the response but transposed by a semitone. Hence in these circumstances, the desire for musical coherence overwhelmed DP’s sense of AP. The fact that he made these mistakes consistently is testament to the strength of his internal model of the piece.

Trial 20, bar 10, top part, WP

Fig. 4.40 Example of a transposition in WP.

Trial 20, bar 14, inner part, WP

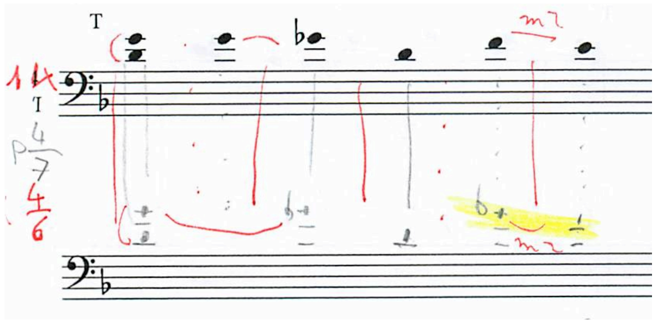


Fig. 4.41 Example of a transposition in WP.

Trial 11, bar 6, inner part, BT

Fig. 4.42 Example of a transposition in BT.

A further recurring mistake was the addition of ‘chromatic’ auxiliary notes in WP (Figure 4.43) and in BT (Figure 4.44).

Trial 1, bar 2, top part, WP

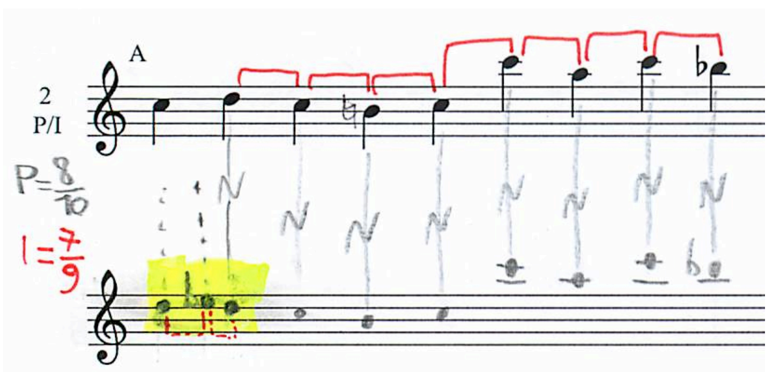


Fig. 4.43 Example of added ‘chromatic notes’ in WP.

Trial 21, bar 7, inner part, BT

Fig. 4.44 Example of added 'chromatic notes' in BT.

Tables 4.19, 4.20, 4.21 illustrate the frequency of systematic errors made by DP trials in the top inner and bottom parts in BT trials. He added notes in all the even numbered bars with the exception of bar 18. Empty boxes in the tables show that either no systematic errors (or no mistakes at all) were made.

Regarding DP's interpretation of the melodic line (the top part), (see Figure 4.19), DP's playful attitude towards music is evident when he adds notes or transposes notes. However, the experiment was not concerned with improvisation and creativity but on the degree of imitation of the stimulus, therefore the criteria used penalized him in terms of the DI achieved.

Table 4.19 DP's systematic mistakes for all BT trials: TOP notes.

Bar	Type of mistakes made: Pitch (P) or Rhythm (R)	Description of the mistakes
1		This bar was always right
2	P and R	P: played one note more at the beginning. R: played a quintuplet instead of quadruplet
3	P	For the first note: played C instead of D
4	P and R	P: the first 5 notes were played at a semitone up. R: same as bar 2, in addition the second to last note it lasted 2/4 instead of 1/4
5		This bar was always right
6	P and R	P: played the second note as a B natural instead of B♭. R: the same as bar 2
7		This bar was always right
8	P and R	P: all right but with an additional note at the beginning. R: the same as bar 2

9	P and R	P and R: Played them all right, but there was a note missing (F) at the beginning
10	P and R	P: played an additional note at the beginning. R: the same as bar 2
11	P and R	Often when he played the first note, he substitutes a quadruplet or quintuplet.
12	P and R	P: played the second note as a F# instead of F natural, and an additional note at the beginning. R: the same as bar 2
13		
14	P and R	P: played E natural instead of E♭ as a second note. R: the same as bar 2
15	P	Played E instead of F# as the first note
16	P and R	Played the first five notes at about a tone lower. R: the same as bar 2
17		This bar was always right
18		
19		

Moving on to the inner part of the score (see Table 4.20), which is more complicated to memorise, more errors are found, although these are less reoccurring. Sometimes DP adds notes, repeating the same additions over time.

Table 4.20 DP's systematic mistakes for all BT trials: INNER notes.

Bar	Type of mistakes made: Pitch (P) or Rhythm (R)	Description of the mistakes
1	P and R	A note was repeated twice, played two As instead of one
2	R	1/4 plus a dot instead of 2/4
3	P	Played C-D-E♭ in an inverse order of E♭-D-C
4		
5		
6	P	Played without the second D, and the last two notes were played in an higher semitone
7		
8		
9	P and R	The same as bar 1
10	R	The same as bar 2
11	P	The same as bar 3
12	P	Played E-B♭ instead of E-G at the beginning of the bar; F#-A-D instead of D-F#-A at the end

13		
14	P and R	Played only one G, and the last two notes were played in an higher semitone
15		
16	P	Played B-F instead of B-D at the beginning
17		
18		
19	P and R	Played an additional G together with the first A, and F# instead of E as a second note

Concerning the bottom part of the score (see Table 4.21), in terms of duration nearly half of the bars in the lower sequence are played incorrectly. On some occasions, the second note is played a demisemiquaver earlier (meaning he played a demisemiquaver instead of a semiquaver, as it was in the stimulus). Therefore, in this case both the duration and the inter-onset are incorrect. This seems to be almost imperceptible for the human ear, especially taking into account that he was simultaneously playing 4 or 5 notes with his right hand, perhaps an example of his dexterous playing ability. It appears that the demisemiquaver is a melodic ornament and the key transposition is applied with playful intention, both a result of DP's adept musical ear.

Table 4.21 DP's systematic mistakes for all BT trials: BOTTOM notes.

Bar	Type of mistakes made: Pitch (P) or Rhythm (R)	Description of the mistakes
1		
2	R	Played the second note 1/32 before
3	R	The same as bar 2
4		
5		
6		
7		
8		
9	P and R	Played as bar 17, played more notes in both P and R
10		
11	R	The first note was shorter, then the inter-onset was ok, but the duration was partially accurate
12	R	The same as bar 11

13		
14	R	The same as bar 11
15	R	The same as bar 11
16		
17	R	The same as bar 11
18		
19	R	The first two notes lasted 1/4 each instead of 4/4 and 2/4. The length was wrong and the inter-onset was ok.

Because of the consistency with which DP added extra notes to the quadruplet turns, a second analysis was carried out which corrected for this systematic error. This increased the overall score by 15%, demonstrating the high impact that this type of mistake had throughout the results.

4.7 Conclusion

The research reported in this chapter explores the nature of DP's musical learning and memory abilities in relation to music. DP was asked to complete a musical memory task, which tested a particular method of learning and involved a novel piece of music: *Classical Turn*.

The *Classical Turn* experiment involved two conditions of learning and recall. In the first, a 'bit at a time' (BT), DP was asked to replicate each bar immediately after hearing it. In the second condition, the 'whole piece', WP, at the end of the first and each subsequent session DP listened to the entire stimulus but was not asked to play it until the beginning of each following session.

In WP, DP achieves low DIs with an average of 0.21. This can be accounted for by the large number of omissions (in the form of whole bars) that he makes. Regarding BT, taking the trials as a whole, DP replicated what he heard with an average DI of 0.62, and the improvement between sessions was minimal and erratic. Better results were expected here, since in a previous experiment, which involved DP learning a piece all the way through, his performance was higher (*cf.*

Chromatic Blues; Ockelford, 2012). Overall, one would expect that by the 14th session, DP would, in broad terms, have memorised the piece, following a period of learning through which DIs gradually increased; however this was not the case.

There appear to be two main reasons for DP's relatively weak performance. First, in WP he invariably omits a number of bars: the most he ever plays is 12 out of 19. Second, in both BT and WP, he persistently adds an extra note to each of the 'turns' that are found in the original, as well as introducing new turns where none was originally present. He frequently made errors pertaining to the rhythm of the bottom part too –repeating pitches – which had a negative impact both on duration and (more rarely) on inter-onset intervals.

The changes in the DIs of the top, inner and bottom parts in WP between sessions are highly correlated with one another, and their means are very similar too. In BT trials, as predicted from the chordal study, DP attained a higher DI in the bottom part, followed by the top and the inner. The differences between the DIs in WP and BT are mainly due to the rhythmic errors that DP makes in the bottom parts of the WP trials. With regard to pitch and rhythm considered separately in the top, inner and bottom parts for WP and BT, unlike in the case of *Chromatic Blues*, DP invariably achieved higher DIs in pitch than rhythm, with the exception of the inner parts of the BT condition.

The pattern of errors that DP makes in both WP and BT gives us insights into the way he attempted to learn the music. In WP most errors recur, although not always appearing in the same bar. That is to say, DP's memory of the stimulus seemed to be a more powerful source of recall than the immediate presence of *Classical Turn* (*cf.* 2.4.1): DP resisted change in what he had learnt, although at some level, given his auditory abilities, we can reasonably assume that had some awareness of what he was doing. A similar tendency is evident in BT, in which his initial errors are crystallised in subsequent attempts. To summarise: in both WP and BT, most errors are systematic, they make musical ‘sense’, and occur in the top and bottom parts.

CHAPTER 5: VERBAL MEMORY TEST

5.1 Introduction

The research reported in this chapter addresses Research Question 3:

Learning and memory in verbal material

In order to further clarify domain-specificity and the possible existence of a music module in working memory:

3) To what extent and in what ways is DP's capacity to learn and recall music domain-specific: in particular, how does it compare with his ability to learn and recall verbal material? Specifically:

> 3a) How do DP's verbal memorisation abilities compare with those of another savant and 'neurotypical' musicians with AP?

To contextualise DP's abilities, these are compared with the verbal memory of another savant (GN) and of two 'neurotypical' musicians with AP who were also involved in the chord disaggregation experiment (see Chapter 3). In a subsequent chapter (Chapter 6) the results of DP's verbal memory test will be compared with his learning and recall of the *Chromatic Blues*, with a view to understanding better the potential modularity of his auditory processing (i.e., to provide evidence for the presence of a distinct 'music processing module': Ockelford, 2007).

5.2 Hypothesis and aims

The hypothesis is formed from combining two models:

- Ockelford (2013, p. 171; see Figure 5.1), which proposes that the usual distinction between music and language processing is weaker in some people with autism (and that some or all of the elements of spoken language become processed in a musical way).

- Ockelford (2007, p. 29; see Figure 5.2), an extension of Baddeley (1986), which proposes that we all possess a distinct music processing module, which is particularly noticeable in savants.

Combining these two models results in a revised memory model for words and music in autistic savants (see Figure 5.3). The arrows within the central executive illustrate how savants tend to divert elements of language to the musical executive to be processed. It is contended that this happens in inverse proportion to the savants' semantic understanding of the stimulus (rather than to its underlying complexity). For example, DP can understand highly complex verbal instructions which relate to music (such as 'Please play this piece in F major, in the style of Oscar Peterson') but struggles to comprehend simple questions about other topics (such as 'How many apples do you have?' as he holds one in each hand).

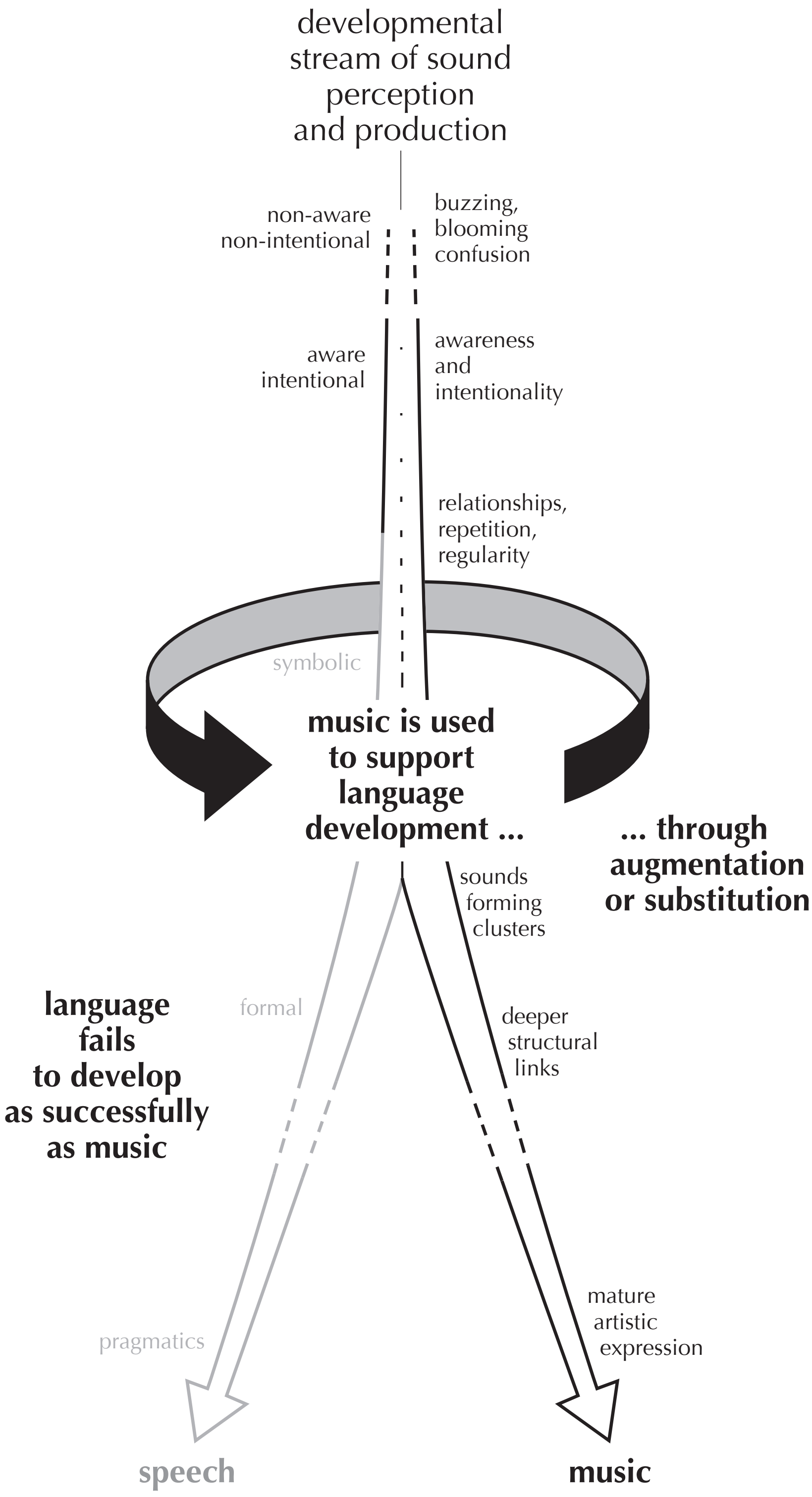


Fig. 5.1 'Musical development may outstrip linguistic development in some children on the autistic spectrum' (Ockelford, 2013, p. 171).

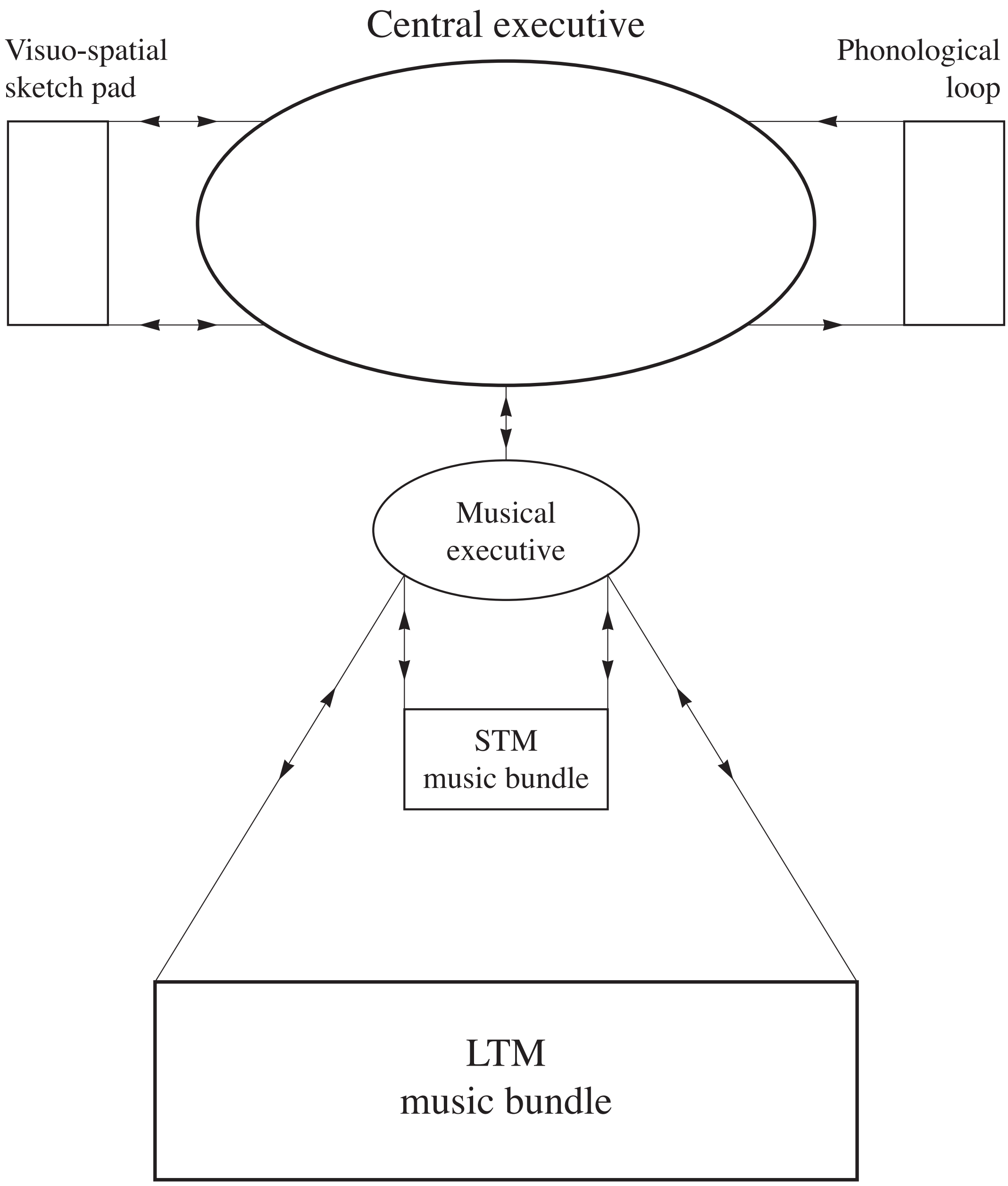


Fig. 5.2 'The possible disposition of a 'music module' in working memory' (Ockelford, 2007, p. 29), based on the premise that musical structure is unique to music. Hence the way music is processed is distinct.

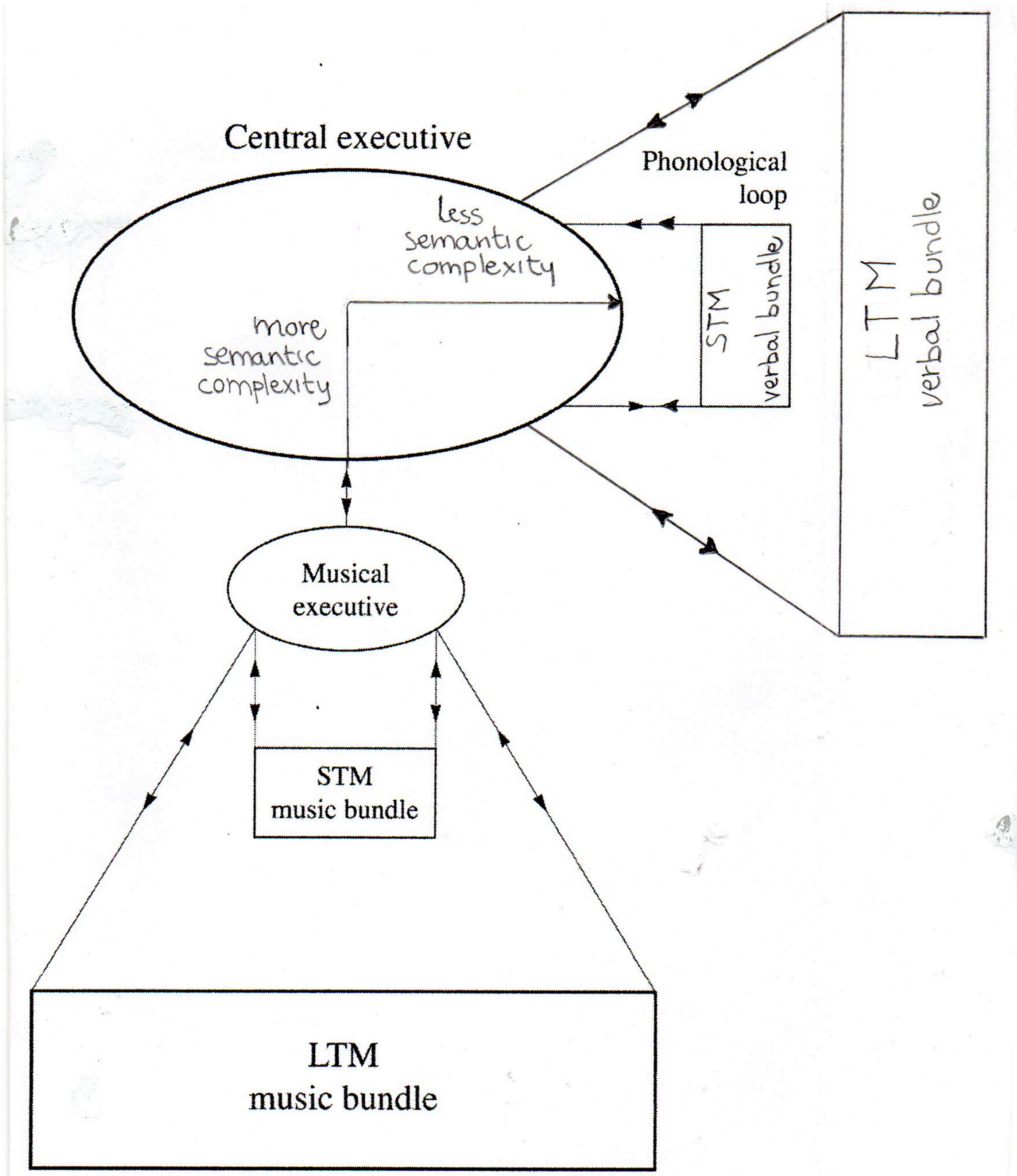


Fig. 5.3 Revised memory model for words and music in autistic savants. Alongside the central executive that processes the language, there is a musical executive that diverts the information to the STM music bundle, which has a pitch, rhythm, timbre and loudness loop. The STM music bundle offers temporary storage, before musical ideas are encoded in LTM.

Some neuropsychologist have suggested that music and language may be processed domain-specifically (Peretz and Coltheart, 2003), whilst evidence from neuroscience (Koelsch, Schmidt and Kansok, 2002; Schmithorst, 2005) indicates linked processing networks. The resource-sharing model suggested by Patel (2012) proposes a merging of these two views, in which language and music are *stored* independently, but share *processing* networks. In addition it has been reported (Järvinen-Pasley et al., 2007) that people with autism demonstrate a tendency to process aspects of language in a musical way. This indicates reduced domain-specificity in auditory processing in autism (Järvinen-Pasley and Heaton, 2007).

Therefore, it is predicted that:

- DP will find remembering the semantic elements of language difficult, but will perform better in relation to the musical elements (compared to the 'neurotypical' participants);
- DP will have more effective LTM for music than language (due to weakness in his phonological loop and supporting executive function) and his processing of the stimuli via the music executive and STM bundle will be relatively strong.

Given the above predictions, the aims of the experiment were to assess DP's verbal memory capacities by testing his recall of a story (see Figures 5.1, 5.2 and 5.2a), comparing his attempts with those of another savant (GN), and two 'neurotypical' participants with AP (AN and LP), who were also involved in the chordal disaggregation experiment (see Chapter 3).

The verbal material that was produced by the participants (responses) was matched against the original text (stimulus). The correspondence between the stimulus and the responses was measured using four different variables (semantics, syntax, sonance and sequence; after Ockelford, 2013); the nature of each variable will be explained in detail below.

5.3 Method: verbal memory test

5.3.1 Participants

The participants in this study were two savants (DP and GN) and two comparison subjects (LP and AN). All four participants also took part in the AP study (*cf.* Chapter 3), and DP participated in the musical memory study (*cf.* Chapter 4). The aim was to ascertain whether DP's verbal memory is similar to his musical memory and to that of another savant (GN), therefore supporting the hypothesis set out in 5.2 above, that DP and GN may have similar, idiosyncratic ways of processing language (see Figure 5.3). Secondly, the study aimed to assess whether the model proposed in Figure 5.3 is relevant to 'neurotypical' people.

5.3.2 Stimuli description

Two structurally identical stories were created based respectively on the lives of DP and GN and written as simple narratives. It was difficult to gauge the appropriate level of language to use because GN is more linguistically capable than DP. The stimulus was written to be suitable for DP, so a potential problem was that GN would find the task too easy, but this could not be avoided without impinging on the validity of the experiment. The nature of the language was concrete, using everyday words and expressions and avoiding abstract concepts. The stories described and praised each individual's ability to play the piano, and listed some of the places in which they had performed (see Figures 5.5, 5.6 and 5.6a). The stories were personal to DP and GN in order to facilitate their ability to remember the information (*cf.* Chapter 3). Participants listened to their story in their native language.

The construction of the text was based on the musical structure used for *Chromatic Blues* and *Classical Turn* (see Figures 4.1 and 4.2 in Chapter 4) for the purposes of comparison. It was hoped that this would make it possible to compare verbal and musical processing accurately, allowing the identification of, for example, primacy and recency effects (Postman and Phillips, 1965) and the impact of repetition and transformation. The story was therefore structured in five segments; as in *Chromatic Blues* (Figure 5.4) and *Classical Turn*, the first segment was approximately equal in length and content to the third, the second similar to the fourth, and the fifth a ‘coda’, (Figures 5.5 and 5.6) which consisted of information relevant to, but not duplicated in, segments 1 to 4. Note that there were fewer words in the verbal stimuli (78, 92) than notes in the musical stimuli (approximately 400 in each piece), to ensure that the verbal text was much simpler than the musical one.

$A_{1.1}$	$B_{1.1}$	$A_{2.1}$	$B_{2.2}$	C
Theme A – exposition	Theme B – exposition	Theme A – reprise	Theme B – transposed, extended	Coda

Fig. 5.4 *Chromatic Blues’* structure (see Chapter 4, Figure 4.2 for the musical score).

For the experiment with AN, the English non-savant comparison participant, Derek’s story was used, and Gabriele’s story was used for LP, the Italian non-savant comparison. There was a slight variation between the Italian and English stories resulting from translation, and the number of words inevitably differed slightly in order to produce idiomatic language. In the story used for DP and AN, segments 1 and 3 comprised 17 words, segments 2 and 4 consisted of 16 and segment 5 had 12. The total number of words was 78. In the story used for GN and LP, segments 1, 3 and 4 contained 21 words, segment 2 consisted of 20 and segment 5 had 9 words. The total number of words was 92. However, the story’s structure and essential meaning was maintained.

Derek's story

Once upon a time there was a young man called Derek, who loved to play the piano,

in London and Las Vegas, and Redhill and Ramsgate – and everybody clapped when they heard him play.

Once upon a time there was a young man called Derek, who loved to play the piano,

in Warfield and Wimbledon, and Holland and Hollywood – and everybody cheered when they heard him play:

'Well done, Derek!' 'Good old Derek!' 'He's a magical music man!'

Fig. 5.5 The five segments of Derek's story.

Gabriele's story

Una volta tempo fa', c'era Gabri e il suo piano, bravo bravo Gabri al piano, Luca e Gabri sono ok.

Jazz Studiava classica e pop e tutti le mani battevano forte, a Cosenza, Milano, Torino, Pavia. Ottimo Gabri continua cosi'.

Una volta tempo fa c'era Gabri e il suo piano, bravo bravo Gabri al piano, Luca e Gabri sono ok.

Leggeva la musica, suonava a memoria, e Rosa ballava se lui suonava, a Cosenza Milano, Torino, Pavia, Ottimo Gabri continua cosi'.

Bene Gabri! Magico al piano! Bello Gabri! Fantastica mano!

Fig. 5.6 Gabriele's story.

English translation of Gabriele's story

Once upon a time there was Gabri and his piano. Well done Gabri for playing the piano. Luca and Gabri are OK.

He knows and plays jazz, classical and pop. Each time he plays, people clap loudly – at Cosenza, Milano, Torino, Pavia. Excellent Gabri, keep it up!

Once upon a time there was Gabri and his piano. Well done Gabri for playing the piano. Luca and Gabri are OK.

He reads the music and plays it by heart. When he plays Rosa dances – at Cosenza, Milano, Torino, Pavia. Excellent Gabri, keep it up!

'Well done Gabri – magical player! Good Gabri! Fantastic pianist!

Fig. 5.6a English translation of Gabriele's story.

5.3.3 Timetable

The timetables for the sessions with the participants are given below (Tables 5.1 to 5.4). These were based on the timetables for the musical memory tests (involving *Chromatic Blues* and *Classical Turn*, *cf.* 4.4.2). The same general pattern of sessions was maintained for the verbal memory test for comparison purposes. However, there were some slight differences in the number of days between sessions due to participants' schedules (*cf.* 4.4.2). Although not originally intended, GN had fewer sessions than DP, because he learnt the story in less time and subsequently chose not to continue with the sessions. AN and LP had fewer sessions due to constraints on their time.

Table 5.1 Pattern of the sessions for the verbal memory experiment for DP

DP			
Session number	**Trials**	**Days since previous session**	**Periods between sessions**
1	1	-	2 weeks
2	2&3	2	
3	4&5	5	
4	6&7	2	
5	8&9	7	
6	10&11	25	1 month
7	12&13	2	2 weeks
8	14&15	6	
9	16&17	2	
10	18&19	5	
11	20&21	96	3 months
12	22&23	190	6 months
13	24&25	422	1 year
14	26&27	735	2 years
Total	**27**	**1499**	**4 years**

Table 5.2 Pattern of the sessions for the verbal memory experiment for GN.

GN			
Session number	**Trials**	**Days since previous session**	**Periods between sessions**
1	1	-	2 weeks
2	2&3	2	
3	4&5	5	
4	6&7	2	
5	8&9	7	
6	10&11	26	1 month
7	12	310	<1 year
Total	**12**	**352**	**1 year**

Table 5.3 Pattern of the sessions for the verbal memory experiment for AN.

AN			
Session number	**Trials**	**Days since previous session**	**Periods between sessions**
1	1	-	2 weeks
2	2&3	2	
3	4&5	5	
4	6&7	2	
5	8&9	8	
6	10&11	29	1 month
7	12&13	3	
Total	**13**	**49**	**1 month and 2 weeks**

Table 5.4 Pattern of the sessions for the verbal memory experiment for LP.

LP			
Session number	**Trials**	**Days since previous session**	**Periods between sessions**
1	1	-	2 weeks
2	2&3	2	
3	4&5	5	
4	6&7	2	
5	8&9	8	
6	10&11	29	1 month
Total	**11**	**46**	**1 month and 2 weeks**

5.3.4 Procedure for DP

The story was recorded before the experiment began using a digital recorder by Adam Ockelford (see 3.3.2), so that DP would be hearing a familiar voice. It was played to him via an MP3 player. As soon as he had finished listening to the story, he was asked to repeat it to the researcher. In order to give DP a clear understanding of the task and to distinguish it from the previous experiment, the title 'Derek's story' was given to the verbal test.

The following shows the protocol for each session of the verbal memory test:

Session 1:

1. DP listens to the whole story.
2. DP repeats the whole story (as best he can).
3. DP listens to the whole story again, but makes no attempt to repeat it.

In more detail:

Sequence	Instructions
1.	AM says: *'Now, Derek, I am going to play you 'Derek's story'. Listen carefully and then tell me what you can remember'.*
2.	AM plays the story.
3.	AM says: '*Derek, now it is your turn. Please tell me what you can remember'.*
4.	DP repeats the story (as best he can).
5.	Then, AM says: *'Here is the story again'.*
6.	AM plays the story again.
7.	AM says: *'Thank you Derek. Let's have a break'.*

From Session 2 to Session 27

The procedure below was followed for all subsequent sessions.

1. DP attempts to tell the whole story.
2. DP listens to the whole story.
3. DP repeats the whole story again.
4. DP listens to the whole story again.

In more detail:

Sequence	Instructions
1.	AM says: *'Hi Derek. Please tell me what you can remember of Derek's story'.*
2.	DP tells what he remembers of the story.
3.	AM says: *' Now listen to the story'.*
4.	AM says: '*Now your turn. Please tell me what you can remember'.*
5.	DP says: what he can remember.

6.	Then, AM says: *'Here is the story again'.*
7.	AM plays the story for DP to listen to only.
8.	AM says: *'Thank you Derek. Let's have a break'.*

Location: The majority of the sessions involving DP were conducted at the residential facility where DP lived at the time. Some of the sessions were conducted at DP's mother's home in Lambourn. Although not entirely distraction-free, these are familiar places to DP, in which he felt comfortable, hopefully facilitating his performance.

Participant: Derek Paravicini.

Experimenter: Annamaria Mazzeschi.

Observer: Adam Ockelford.

Equipment: the experiment was recorded using a digital recorder and a video camera.

5.3.5 Procedure for GN

The story was previously recorded onto a digital recorder by Anna Maria Bordin (*cf.* 3.3.4), so that GN would be hearing a familiar voice. It was played to him via an MP3 player. As soon as he had finished listening to the story, he was asked to repeat it to the researcher. In order to give GN a clear understanding of what he was doing and to differentiate between the previous and current experiment, the title 'Gabriele's story' was given to the verbal test.

The following is a description of the verbal memory test:

Session 1:

1. GN listens to the whole story.
2. GN repeats the whole story (as best he can).
3. GN listens to the whole story again, but makes no attempt to repeat it.

In more detail (the following text is a translation of what was said to GN):

Sequence	Instructions
1.	AM says: *'Now Gabriele I am going to read you a short story called 'Gabriele's Story'. Listen carefully and then tell me whatever you can remember'.*
2.	AM plays the story.
3.	AM says: '*Gabriele, it is now your turn. Please tell me what you can remember'.*
4.	GN repeats the story (as best he can).
5.	Then, AM says: *'Here is the story again'.*
6.	AM reads the story again.
7.	AM says: *'Thank you Gabriele. Let's have a break'.*

From Session 2 to Session 12:

This procedure was followed for all subsequent sessions.

1. GN tells what he can remember of the story.
2. GN listens to the whole story.
3. GN attempts stage 1 again.
4. GN listens to the whole story again.

Sequence	Instructions
1.	AM says: *'Hi Gabriele. Tell me what you can remember of 'Gabriele's Story?'.*
2.	GN says what he remembers of the story.
3.	AM says: *'Please listen to the story'.*
4.	AM says: '*Gabriele, it is now your turn, please tell me what you can remember'.*
5.	GN says what he can remember.
6.	Then, AM says: *'Here is the story again'.*
7.	AM plays the story again.
8.	AM says: *'Thank you Gabriele. Let's have a break'.*

Location: The experiment was conducted in two different locations, at the Vittadini Conservatoire in Pavia, Italy (where GN studies music), and at his home in Rivarolo (Ivrea). Although not entirely distraction-free, these are familiar places to GN, in which he feels comfortable, facilitating his performance. This meant that the criteria for ecological validity were met (Neisser, 1995).

Participant: Gabriele Naretto.

Experimenter: Annamaria Mazzeschi.

Observer: Anna Maria Bordin.

Equipment: the experiment was recorded using a digital recorder and a video camera.

5.3.6 Procedure for the non-savant participants

The procedure for the non-savant participants (AN and LP) was the same as for the savant participants (DP and GN). However, fewer sessions were required for AN and LP as they learnt the story in 13 and 11 sessions respectively.

5.3.7 Method of analysis

The experiment consisted of 27 trials for DP, 12 for GN, 11 for LP and 13 for AN; the number of trials for each participant varied because each person learned and retained the story at a different rate. Transcriptions were made of each participant's response in every trial; each one was documented and analysed in detail using four different variables: *semantics, syntax, sonance and sequence*. These variables were used to ascertain the levels of learning and remembering that participants demonstrated; they were chosen from an array of language structures (Ockelford, 2013) since they were of most relevance to the task completed by the participants. The literature suggests that language includes connected domains of communication (Wilkinson, 1998) including pragmatics, semantics, phonology, prosody and syntax. The reason for focusing on *semantics, syntax, sonance and sequence* was based on the assumption that they would enable the research questions to be addressed.

The chosen method of analysis measured the extent to which the participants' responses were derived from their memory of the story (taking into account both long-term memory and the combination of this with working memory), and from other memories not directly derived from the stimulus. The analyses of the text were made by connecting each word of the story (stimulus) with the corresponding word that the participants produced (response), following four different protocols that were dictated by the variables that were examined (see Figures 5.7 to 5.10). To analyse the first variable, semantics, words with the same or similar meaning were linked. For syntax, words with identical or comparable syntactic function were connected. With regard to sonance, words that sounded the same or similar were matched. And for sequence the 'absolute' and relative positions of words were compared. According to zygonic theory (Ockelford, 2012), words that are deliberately repeated (i.e. imitated) have a relationship of *derivation* between them. The extent of the derivation for each segment and variable was summarised in terms of a 'derivation index' (DI). This was calculated by dividing the number of connected words (in relation to each variable) by the total possible number of matches (i.e., the total number of words in the segments of the stimulus).

One potential problem with this method is that participants may have said words that matched some of those in the stimulus by chance. This was most likely to occur with common words (such as 'and', 'a' and 'the'). Therefore, common words were counted as an imitation only if they appeared in the response in the same location as in the stimulus. In addition, if the participants used an incorrect word that had the same syntactic function as one from the stimulus (e.g. both were verbs) but it was in the wrong place in the sentence structure, it is most likely the participant concerned would not have derived it from the story.

On the other hand, less common words such as 'Wimbledon' were scored as having been imitated even if they were placed in the wrong position in the response, because it is highly likely that these words were derived from a memory of the stimulus. Another issue could be if the participants used a word with a similar meaning to one in the stimulus and in the same structural position (for example, 'liked' instead of 'loved'). This could suggest that they derived this word from their memory of the story, and demonstrate that they understood the meaning. Therefore, such cases have been considered as partial imitation.

Figures 5.7 to 5.10 detail the connections that were made between the words in the stimuli and the responses. One challenge of the analysis was the separation of content and structure, as, in language, these are interlinked and so treating them separately is a somewhat artificial thing to do, although an attempt was made, nonetheless. The analyses were presented by transcribing the stimuli and responses next to each other and drawing an arrow from each word of the stimulus to the corresponding word repeated by the participant domain by domain. The following rules were applied in scoring the participants' responses. Any response to the same stimulus that was given twice was only counted once. Names were considered as one word only (e.g. Las Vegas). Conversely, contractions (e.g. 'He's', 'didn't';) were counted as two words. If the word in the response matched the word in the stimulus exactly, according to the variable that was being used, one point was ascribed and a solid arrow used to connect the two corresponding words. If the word in the response was similar but not an exact match (according to the variable) half a point was assigned and a dashed arrow was used to connect the corresponding words. No points were allocated when there was no response or no connection (imitation/derivation) between the stimulus and response. All the arrows were enumerated to provide clarification, so that whenever a connection was not immediately clear, explanation could be provided separately. The score obtained for each segment of the story was written above its final word, and derivation indices calculated.

5.3.7.1 Description of variables analysed

'Semantics' refers to the meaning of words; this variable was used to measure how close in meaning each word in the stimulus was to the relevant word in the response. A scoring system was determined in order to rate the accuracy between stimulus and response: one point was given to each word that was the same and half a point if the meaning was a close match; on the contrary, if the word did not match or the meaning was completely misunderstood and no connections were made, then no points were given.

‘Syntax’ means the grammatical function of a word within a text; this variable was used to measure how similar the stimulus and response were in structure word by word. One point was assigned where the response contained a matched word repeated in the correct place within the sentence. Words which were correct but misplaced (in terms of order) were also allocated one point. Half a point was given to each word that was incorrect in meaning but syntactically correct and in the right place in the sentence structure. No points were given where two different words were syntactically related but were not correctly placed within the story (e.g. two verbs with different meanings and located in different segments), or where two words were similar but syntactically different (e.g. an adjective and a noun: ‘music’ and ‘musical’).

‘Sonance’ refers to the sound of a word. One point was given for each word in the stimulus that was matched exactly in the response (e.g. ‘loved’ and ‘loved’) and half a point for each word that was different but similar in sound (e.g. ‘when’ and ‘then’). The position of the word in the response was also taken into consideration (see above). Where the response included incorrect words, which were similar in sound, and the sequence of the sentence was maintained, half a point was given. However, where the response contained an incorrect word that sounded similar to a word in the stimulus but was misplaced (e.g. in the stimulus the word was at the beginning but in the response it was repeated at the end of the story), no points were given.

‘Sequence’ is the order in which words are presented, so can only be considered in relation to at least two words. This is important because the more words the participants recalled in the correct order, the more likely it was that they were actually remembering the stimulus (rather than guessing). There are two aspects of sequence: ‘absolute’ and ‘relative’ position. Both were taken into consideration whilst analysing the text. ‘Absolute sequence’ means the position assumed by the word or words with respect to the entire original text, i.e., if the original structure is maintained (what is before and what is after). Relative sequence is the position assumed by a word within a phrase. When both aspects were satisfied in the participants' responses, one point was assigned; half a point was given where either relative or absolute sequence but not both was correct. Points or half points were given only when two words were articulated subsequently and without any other words in between. A connection was made with a curved arrow for every word that was in the right place; summing all of these connections provided the total score. A word which was partially (semantically or syntactically) correct was linked with the next corresponding word through a dashed arrow, and each connection before or after was given half a point. Words that were located incorrectly did not take any points, apart from a few cases: if the participant combined two adjacent segments, a point could only be given for the final word. Where the first two words in a segment were correct, each was allocated one point (one for the first word in the correct position and one for the relative sequence of the first two words), but if the second word was incorrect, the first word scored only half a point. Words which were in the correct segment but out of sequence also scored half a point. For the list of locations in segments two and four, half a point was assigned if the first and last locations were in the correct positions, even if those in the middle of the list were incorrectly placed.

5.4 Results

5.4.1 Example analysis of participants' responses

Session 2, trial 1, of DP's responses is given below as an example of how the analysis was performed throughout, showing the method used to establish derivation indices. As mentioned above, the story was divided in segments, and the analysis was performed discretely for each segment using the four variables (semantics, syntax, sonance and sequence).

Figures 5.7, 5.8, 5.9, 5.10 show the analysis of the text for each variable:

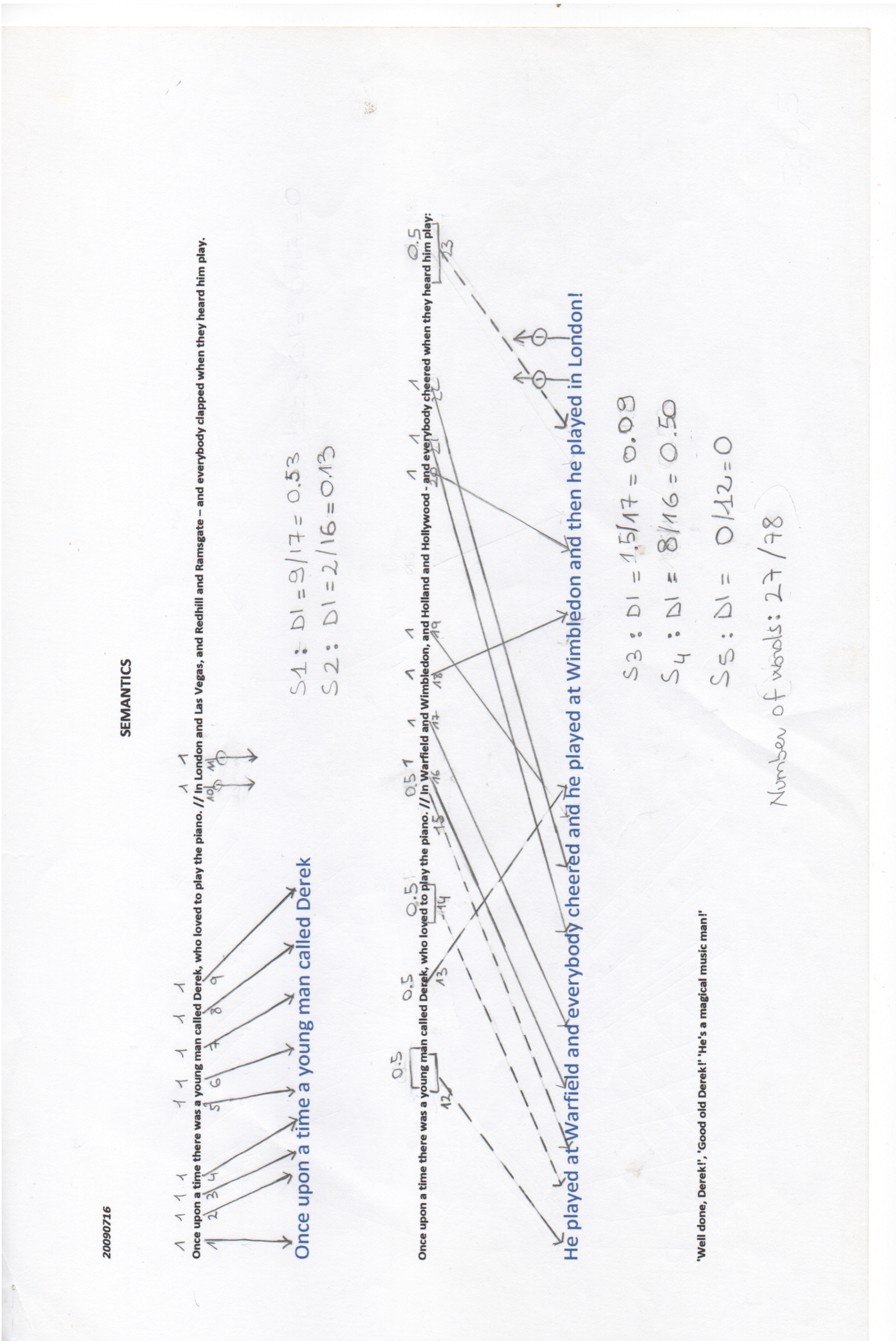


Fig. 5.7 Analysis of semantics for DP in session 2, trial 1.

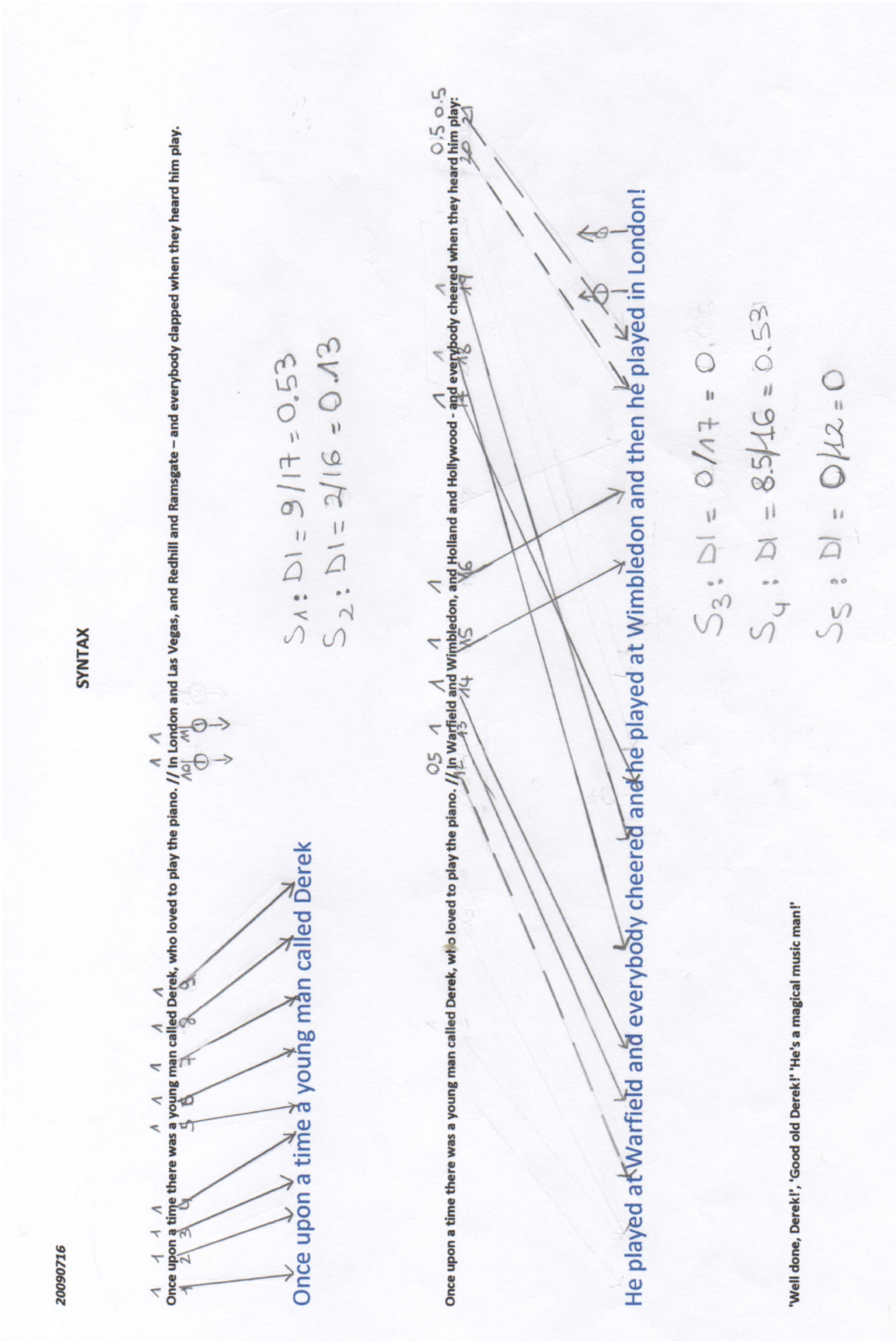


Fig. 5.8 Analysis of syntax for DP in session 2, trial 1.

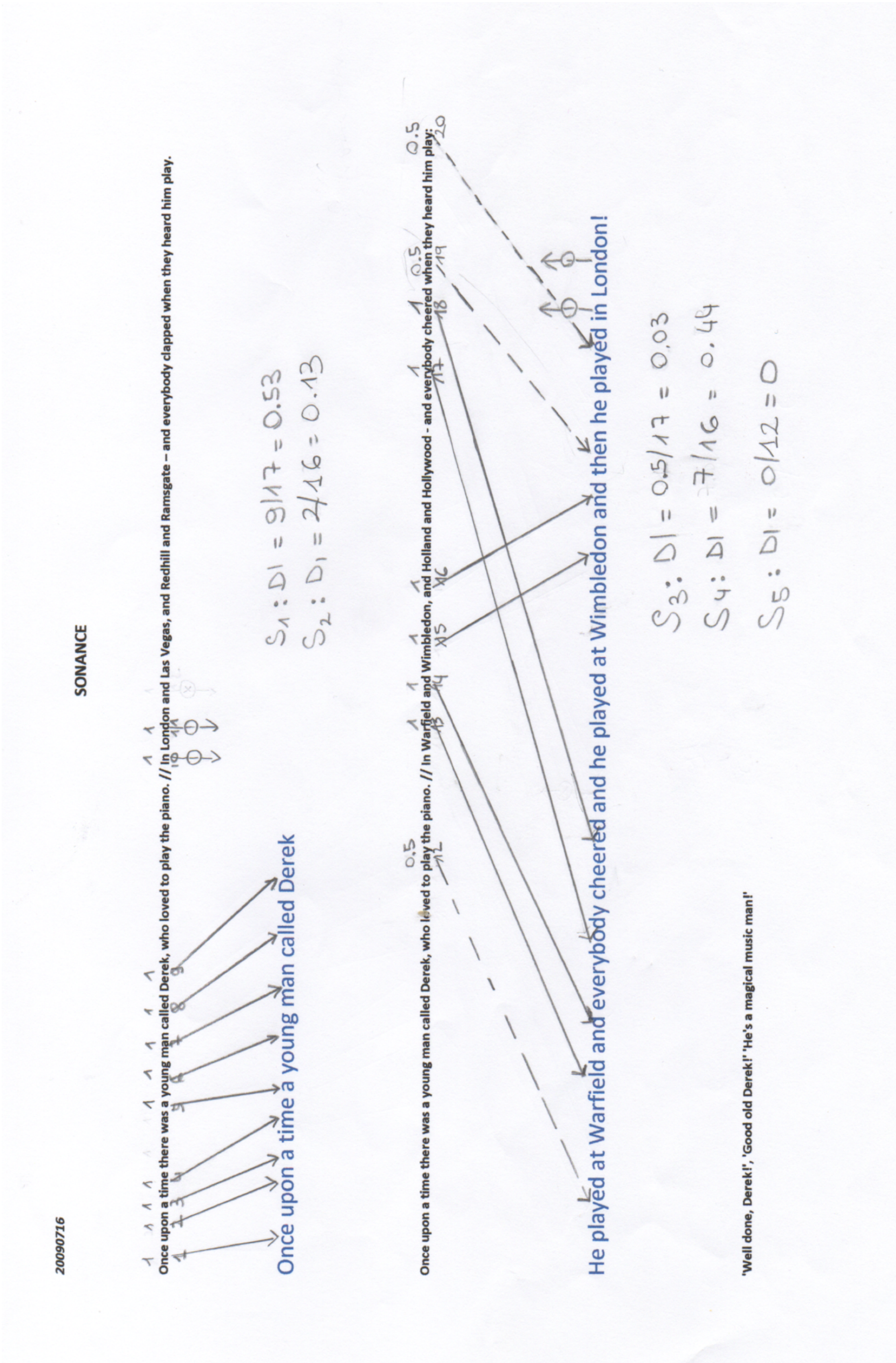


Fig. 5.9 Analysis of sonance for DP in session 2, trial 1.

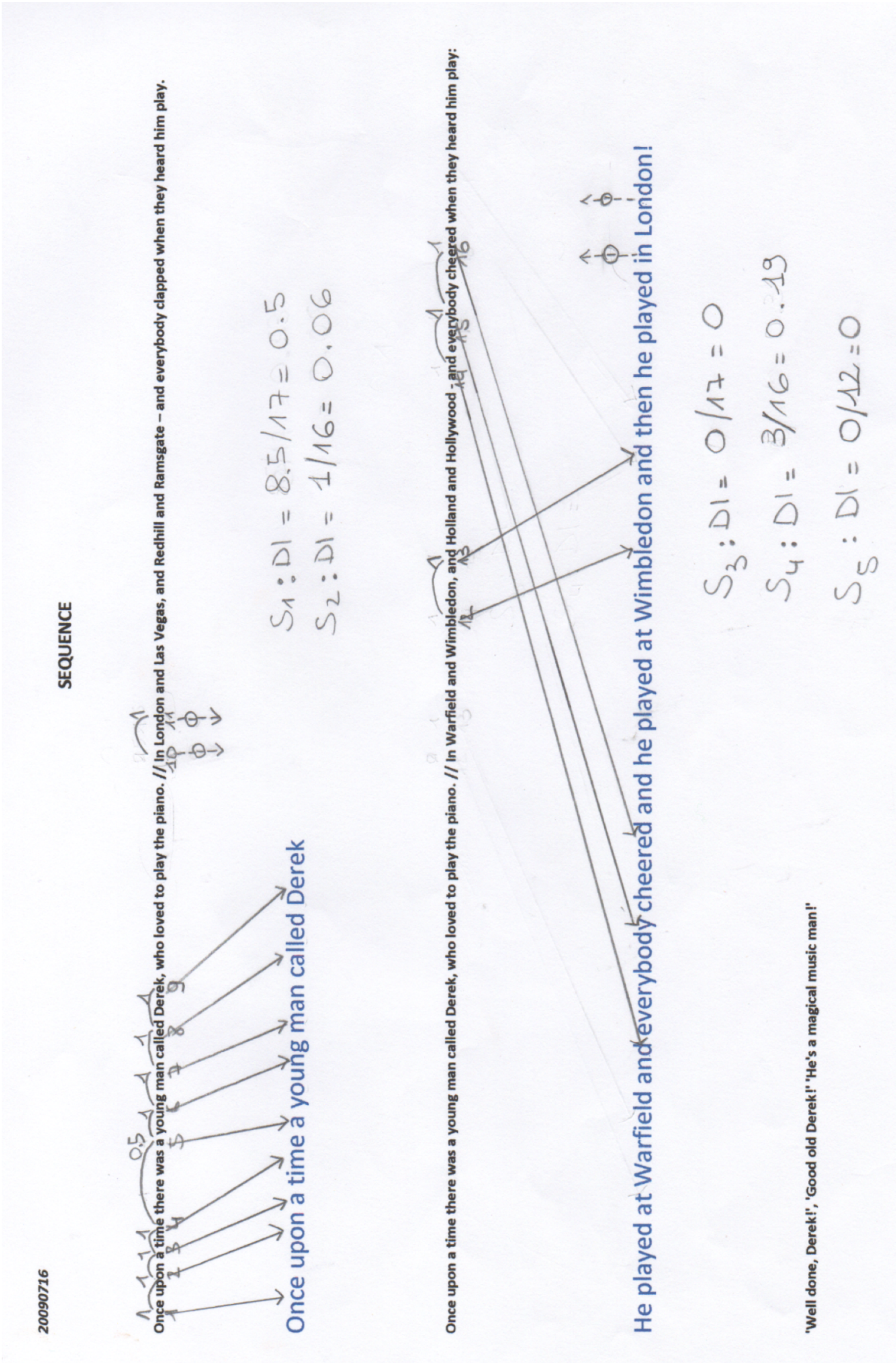


Fig. 5.10 Analysis of sequence for DP in session 2, trial 1.

Tables 5.5, 5.6 and Figure 5.11 give the scores obtained by DP in the second session, trial 1.

Table 5.5 Score obtained by DP in the second session, trial 1, taking into consideration variables and segments.

	Variables	Length of segment (words)	Score (words correct)	Derivation Index
Segment 1	Semantics	17	9	0.53
	Syntax	17	9	0.53
	Sonance	17	9	0.53
	Sequence	17	8.5	0.50
Segment 2	Semantics	16	2	0.13
	Syntax	16	2	0.13
	Sonance	16	2	0.13
	Sequence	16	1	0.06
Segment 3	Semantics	17	1.5	0.09
	Syntax	17	0	0
	Sonance	17	0.5	0.03
	Sequence	17	0	0
Segment 4	Semantics	16	8	0.50
	Syntax	16	8.5	0.53
	Sonance	16	7	0.44
	Sequence	16	3	0.19
Segment 5	Semantics	12	0	0.00
	Syntax	12	0	0.00
	Sonance	12	0	0.00
	Sequence	12	0	0.00

Table 5.6 Mean DI for each variable.

Semantics (segments 1-5)	0.25
Syntax (segments 1-5)	0.24
Sonance (segments 1-5)	0.23
Sequence (segments 1-5)	0.15

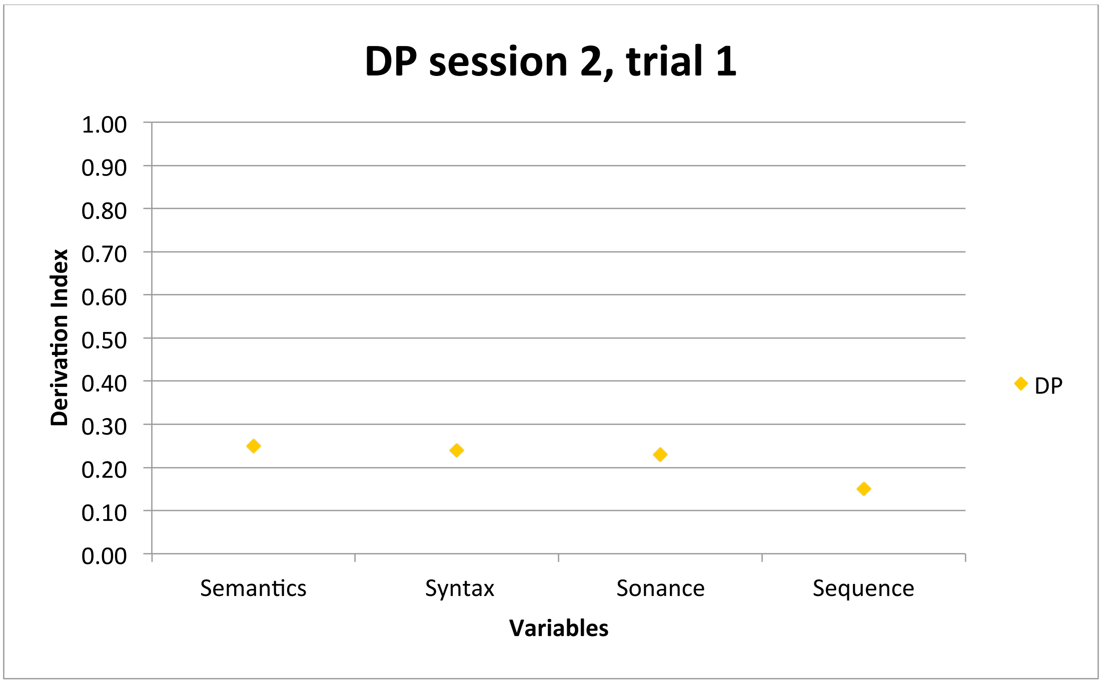


Fig. 5.11 DP's mean DI for each variable in session 2, trial 1.

In session 2, trial 1, DP recalled only half the story. The first excerpt was accurate, he omitted the second, combined the third and the fourth and omitted the last (5th). Tables 5.7, 5.8, 5.9 and 5.10 explain in detail the method used to determine how each word was scored.

Table 5.7 Analysis explanation (semantics).

SEMANTICS				
ARROW NUMBER	STIMULUS	RESPONSE	SCORE	COMMENTS
12	young man	he	0.5	The connection is made because DP used a pronoun equivalent in meaning, but did not use the correct word. Pronouns are often problematic for people with autism (Ockelford, 2013)
13	Derek	he	0.5	See arrow 12
14	loved to play	played	0.5	The connection is partial as the meaning is not completely the same
15	in	at	0.5	The connection is partial as *in* and *at* are not identical in meaning. This is an example of DP's misuse of prepositions (Ockelford, 2013)
22	cheered	cheered	1	Complete connection between words
23	heard him play	played	0.5	Partial connection because the meaning is altered with the use of a different phraseology

Table 5.8 Analysis explanation (syntax).

SYNTAX				
ARROW NUMBER	STIMULUS	RESPONSE	SCORE	COMMENTS
8	called	called	1	The two words are syntactically equal
12	in	at	0.5	Both are prepositions, with similar meaning
20	him	he	0.5	Both are masculine third person pronouns, but in different grammatical 'persons'.
21	play	played	0.5	The correct verb was used but in a different tense

Table 5.9 Analysis explanation (sonance).

SONANCE				
ARROW NUMBER	STIMULUS	RESPONSE	SCORING	COMMENTS
12	play	played	0.5	Different tense
15	Wimbledon	Wimbledon	1	The two words are the same
19	when	then	0.5	They rhyme

Table 5.10 Analysis explanation (sequence).

SEQUENCE				
ARROW NUMBERS	STIMULUS	RESPONSE	SCORING	COMMENT
10,11	In London	In London	0.5, 0.5	Relative sequence (internal/between the two words) is maintained; absolute sequence (external/to the broader context) in not maintained as the stimulus was located in the 2nd segment and the response was in the 5th segment.
12,13	Wimbledo n and	Wimbledon and	1,1	Absolute sequence is maintained (internal/between the two words and external/pertaining to the broader context) as the stimulus and the response were identical and occur in the same place (4th segment)

5.4.2 DP's results for semantics, syntax, sonance and sequence over all trials

Figure 5.12 displays the score achieved by DP for each variable for the entire story, the *x-axis* represents the score obtained for the story, which is differentiated by the four variables (semantics, syntax, sonance and sequence). DP achieved similar results for semantics, syntax and sonance. However he attained a lower score for the sequence variable. There are no statistically significant differences between the variables. This suggests that DP processed semantics just as effectively as sonance. The following paragraph discusses the types of errors that were made by DP. The language of the stimulus was intended to be well within DP's grasp, and so there was no bias against semantics or syntax, that may have occurred with a more complex text. As we shall see the hypothesis of the existence of a 'music module' in working memory could be more applicable to people with autism who do not understand the language they are hearing, meaning that they compensate by focusing on and extracting melodic information from the message (Järvinen-Pasley et al., 2007).

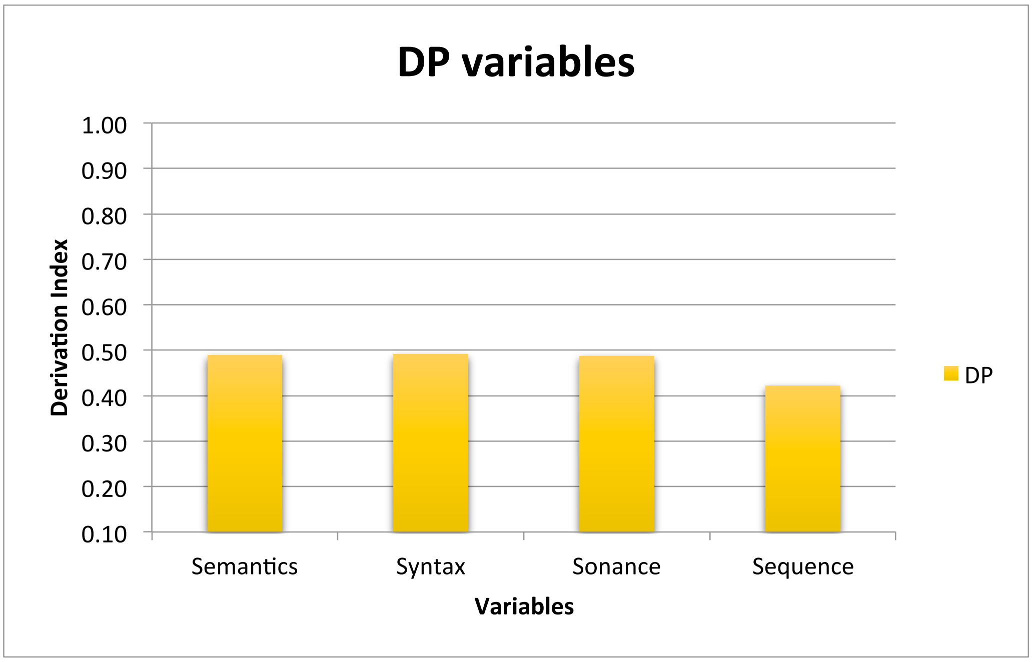


Fig. 5.12 DP's results per variable over all trials.

5.4.3 DP's results for different segments over all trials

Figure 5.13 indicates DP's achievement in the verbal memory experiment both in each segment and per variable. The numbers on the *x*-axis represent the number of segments within the story and those on the *y*-axis the percentage of accuracy. The different lines in the chart signify the variables utilised (semantics, syntax, sonance and sequence) to analyse the DP's memory of the test.

DP achieved the highest scores in the first and fifth segments; this means that he recalled the beginning and the ending of the story better, whilst the lowest score was obtained for the third segment. This suggests a recency and primacy effect. Alternatively, it could be that DP did not comprehend the structure of the story, as segments 1 and 3 are the same. Further examination of the variables in each segment indicates that in the first and fifth segments, higher scores were achieved for *all* variables; in the second and fourth segments, DP performed with less accuracy in relation to sequence. For the third segment his performances for each variable were almost the same.

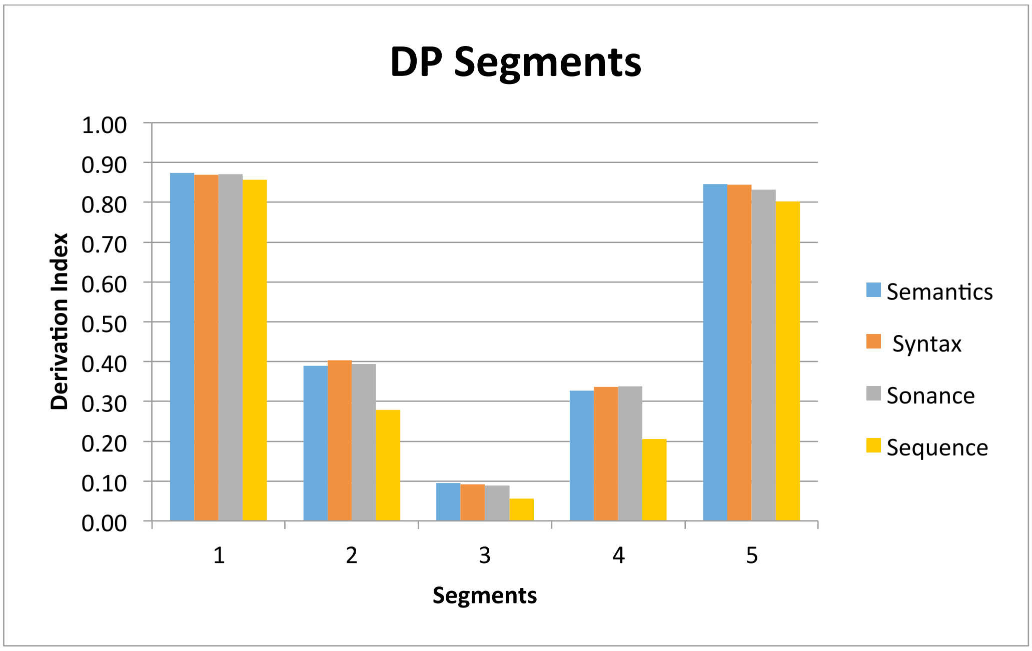


Fig. 5.13 DP's results per segment in over all trials.

5.4.4 Qualitative analysis of DP's production across all the sessions

DP's responses, in the various repetitions of the task, summarised the general content of the story. He did not maintain the original structure. Some mistakes that he made showed the limitation of his linguistic memory (e.g. in the case of paraphrases). Some trials evidenced his echolalia (Ockelford, 2013) as he kept repeating certain words. This may be as a consequence of his lack of understanding. The majority of errors that he made were omissions; he did not follow the repetitions in the story, which were present in order to emulate the repeated nature of musical test (*Classical Turn*, *cf*. Chapter 5).

Given DP's intuitive understanding of musical structure (Ockelford, 2012) it could have been predicted that DP (with his bias towards musical processing) would have got the repetitive structure of the story correct, but this was not the case. This suggests he was using language-specific processing to remember and recall the story, as he privileged the content of the story at the expense of the structure. DP summarised the text instead of repeating the stimulus exactly. In each session, he recalled better the first and the last sentences whilst omitting segment 3 and combining segments 2 and 4 in one sentence (1 and 3 are identical, 2 and 4 differ only in the list of places where he had performed). In the first few sessions, he added sentences that were not present in the stimulus and for two sessions he did not repeat the last sentence.

Learning and production in general are at a low level. Even after 27 sessions (more than double the number needed by the 'neurotypical' participants to learn the story), he still kept omitting the third segment and merging the second and the fourth. Nevertheless, from a low starting point, the accuracy of his production did initially increase before fluctuating. The last two sessions (both done on the same day) occurred after a break of two years; in the penultimate session DP seemed to have forgotten a little of the last sentence, however the rendition was almost the same as that of two years before. In the final session, he produced the same amount of verbal material that he generated two years before, demonstrating that he had learnt and consolidated the story incorrectly in his long-term memory. DP's most frequent errors were omissions of parts of the stimulus; considerable additions of words occurred only in the first session. Through all the sessions he inserted many conjunctions (e.g. 'and'), which were not present in the stimulus.

5.4.4.1 DP's omissions and additions (semantics, syntax and sonance errors)

Table 5.11 shows the total number of words in the stimulus and the number of times DP recalled words from the stimulus correctly, omitted words and added words. For Table 5.11 and those that follow, derivation indices apply to words that are correctly imitated, and percentages have been used to describe the proportion of omissions and additions. The derivation indices and the percentages of the words correctly repeated and those omitted were calculated in relation to the total number of words in the stimulus, while the percentage of the words added by each participant was found by comparing the number of additional words with the total number of words that they produced.

Table 5.11 DP's word production across all sessions.

DP	TOTAL WORDS IN THE STIMULUS	WORDS CORRECTLY REPEATED	WORDS OMITTED	WORDS ADDED	TOTAL WORDS PRODUCED
Number	2,106	1,076	1,030	100	1,176
Derivation Index		0.51			
%			49%	9%	

There were complete or partial matches between DP's response and the stimulus 1,076 times over all the sessions. This means that DP repeated the same or similar words that were in some way related to the stimulus. The total number of words in the stimulus across all the sessions was 2,106. Therefore he omitted 49% of the stimulus. During the 27 sessions, DP omitted 1,030 words and added 100 more (within the 100, 27 were new and 73 he took from the stimulus and repeated multiple times), which means that 9% of the total production was additional words (both new and repeated). The words he frequently repeated were connectors like 'in' or 'and'. Some of the words that he added were not correct but were related, for example he said 'Berkshire' which was not present in the stimulus, however it had a semantic resonance with 'Redhill'. In this case it seems that he remembered the category (places) and substituted 'Berkshire' for 'Redhill'. The total number of words produced by DP was 1,176; this number is obtained by adding the correct repetitions and the added words. Omissions were concentrated in the middle segments (2,3 and 4) in all sessions, with the exception of the first session, where there was no clear difference between segments; as noted above the fact that DP generally omitted the middle parts of the story shows a clear recency and primacy effect.

5.4.4.2 Analysis of DP's sequence

Tables 5.12 and 5.13 below show the stimulus and Derek's responses in specific trials, and the number of times within those trials that particular errors were repeated.

Table 5.12 DP's sequence.

Stimulus	**'a young man called Derek'**	**Trial no.**	**No. of times**
Response	'a band called'	1	1
		16	1
	'called De…'	20	1
Stimulus	**'who loved to play'**		
Response	'I used to play'	1	2
	'he likes to'	6	1
	'who likes to playing'	8	1
	'who loves to'	9	2
Stimulus	**'He's a magical music man'**		
Response	'magical musical man'	6	1
		22	
	'Derek is'	8	1
		4	
	'It is'	24	1
	'magic music'	24	1
	'he was such'	26	1
	'he was'	3	1

DP's sequence seems to be partially maintained, however he scored lower for this, compared with the other variables (semantics, syntax, sonance).

As can be seen in the Table 5.12 above, many phrases that were syntactically incorrect kept the relative structure of the sequence. For example 'who loved to play' became 'I used to play' (occurred twice), 'he likes to play', 'who likes to playing' and 'who loves to play'. In all these errors the structure of the sequence is clearly maintained; this discrepancy (between sequence and the other variables) provides evidence that the sequence is partially independent of the other variables.

Table 5.13 below describes the errors made by DP in the section of the story which listed locations. For the majority of the time DP preserved the relative structure, however, he occasionally added new cities to the list, perhaps using his long-term memory of the places in which he has performed.

Table 5.13 DP's sequence.

Stimulus	**'in London and Las Vegas, and Redhill and Ramsgate…'** **'in Warfield and Wimbledon, and Holland and Hollywood…'**	**Trial no.**	**No. of times**
Response	'in Wimbledon and I used to play in Warfield and in Wimbledon'	1	1
	'in Las Vegas, Wimbledon, Warfield'	6	1
	'in Ramsgate in Warfield in Holland and in Las Vegas'	10	1
	'in Holland, in Las Vegas, in Warfield, in Wimbledon in Redhill in Ramsgate'	11	1
	'in Ramsagate and Wolfield and Holland, in Las Vegas in Ramsgate'	12	1
	'in Warfield in Las Vegas, in Holland in Ramsgate'	13	1
	'in Wimbledon, in Las Vegas in Warfield in Holland'	8	1
	'in Las Vegas, in Warfield and in Holland'	9	1
	'in Warfield in Barkshire in Ramsgate in Wimbledon- in Holland'	14	1
	'Ramsgate in Las Vegas, in America'	15	1
	'in Warfield in Las Vegas, in Ramsgate and Holland'	16	1
	'in Warfield and in Ramsgate and in Holland'	17	1
	'in Las Vegas in Ramsgate and Holland'	18	1
	'in Ramsgate in Las Vegas'	19	1
	'in Las Vegas in Warfield and Ramsgate'	20	1
	'in Warfield in Las Vegas in Ramsgate'	21	1
	'in Las Vegas in Holland in America'	22	1
	'in Hollywood in Ramsgate in Las Vegas and Holland'	22	1
	'in Ramsgate in Las Vegas in Hollywood and in Hollywood and in Holland'	24	1
	'in Ramsgate in Warfield in Las Vegas'	25	1
	'in Hollywood, Las vegas and Holland and Warfield and and Barkshire'	26	1
	'in Warfield, in Ramsgate and Redhill'	27	1
	'at Warfield an in Berkshire and in Wimbledon and in London'	3	1

	'Derek lived in Las Vegas, into Las Vegas- in Warfield and played in Wimbledon and in London'	4	1
Stimulus	**'and everybody clapped-and everybody cheered'**		
Response	'and everybody clapped and cheered'	9	1

5.4.5 GN's results for semantics, syntax, sonance and sequence over all trials

Figure 5.14 shows the score achieved by GN for the entire story across all trials; GN achieved similar results for semantics, syntax and sonance (with a small discrepancy for the latter) but a much lower score for sequence. The compiled data suggest that GN processes the variables similarly, as there are no statistically significant differences between the average score obtained.

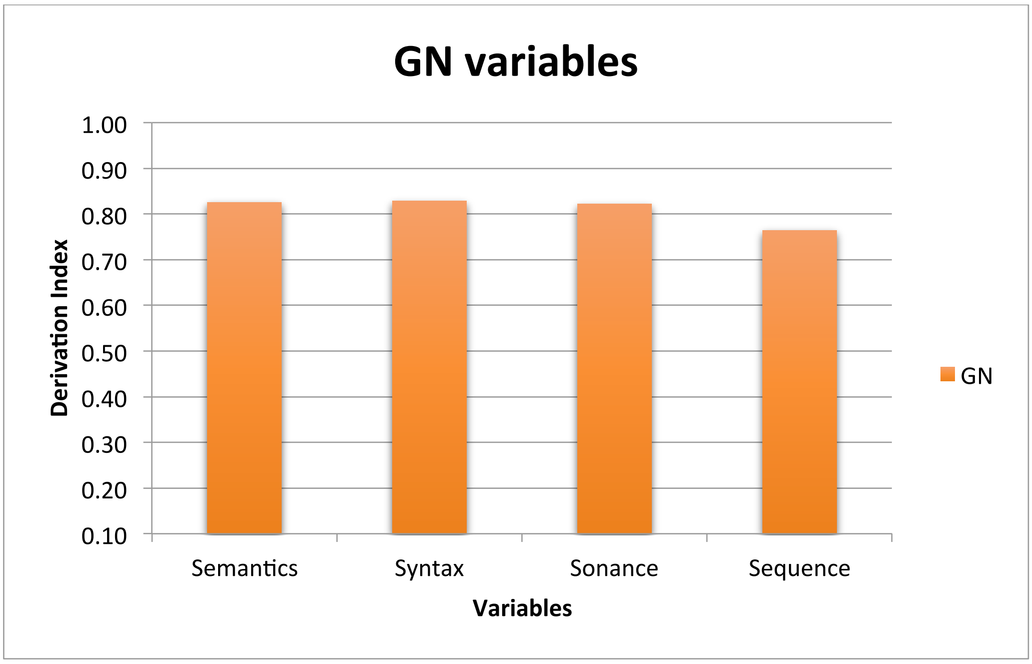


Fig. 5.14 GN's results per variable in over all trials.

5.4.6 GN's results for different segments over all trials

Figure 5.15 displays GN's verbal memory performance results; GN's scores were almost equal in every segment (as he remembered the whole story consistently throughout) as well as across the variables, with the exception of the lower scores achieved in the sequence variable on the second and fourth segments. There are no statistically significant differences between the scores in each segment; therefore the results do not show a primacy, recency or structural effect. GN achieved very high scores, presumably the task was too easy for him.

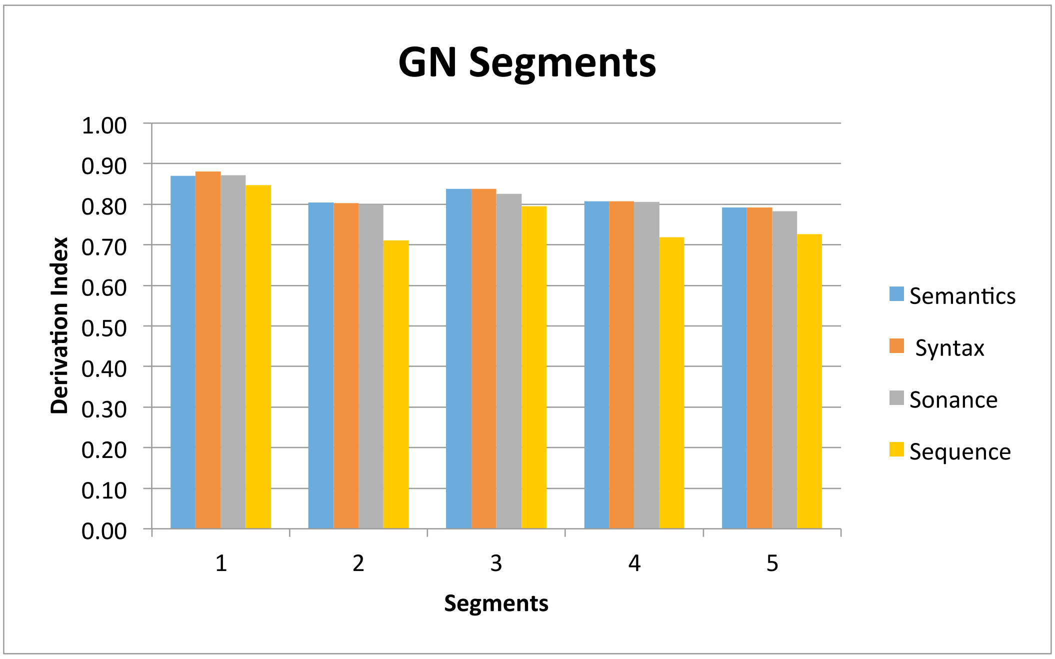


Fig. 5.15 GN's results per segment in over all trials.

5.4.7 Qualitative analysis of GN's production across all the sessions

GN produced very full responses in the first 3 sessions, although he did not repeat the stimulus correctly. He included additional information and digression, probably because he realised that the story was about him. Noticeably, from the fourth session, his responses started to become more accurate. In the first two sessions sequence was very poor, but improved from the third session, although here he made the mistake of mixing up the order within the two lists of places. From the fourth session sequence was completely correct. There were very few omissions and his response became almost perfect from the fifth session onwards. He learnt the whole story completely in 13 sessions. His responses were more accurate than the 'neurotypical' participants', with the exception of his first response, which was very different from the stimulus. Subsequently, he made trivial errors such as ‘Gabriele’ instead of ‘Gabri’ on four occasions and eight syntactic errors like ‘bravi’ instead of ‘bravo’ were made. In one session he substituted the ‘r’ with the ‘l’ (e.g. ‘Gabli’ or ‘blavo’), probably denoting that he was uninterested, suggesting that he did not find the task stimulating enough. He made 1/3 fewer errors than the comparison subjects and his errors were less notable. The few errors that he made were syntactic (no mistakes were made for semantics, sonance or sequence), demonstrating a high level of linguistic competence including an excellent verbal memory.

5.4.7.1 GN’s omissions and additions (semantics, syntax and sonance errors)

Table 5.14 shows the number of times GN made omissions, repeated the stimulus in a correct way, the total number of words of the stimulus and the words he added:

Table 5.14 GN’s word production across all sessions.

GN	TOTAL WORDS IN THE STIMULUS	WORDS CORRECTLY REPEATED	WORDS OMITTED	WORDS ADDED	TOTAL WORDS PRODUCED
Number	1,196	962	234	221	1,183
Derivation Index		0.80			
%			20%	19%	

There was a complete or partial match between GN’s response and the stimulus 962 times. The total number of words in the stimulus for the completed sessions was 1,196. Therefore, the total number of words omitted was 234, a proportion of 20%.

During the 13 sessions GN added 221 words that were either present, partially linked or not in the stimulus; these additions comprise 19% of the total production. The total number of words (1183) in GN’s responses was the sum of the correct words and the added words. Many of the added words were redundant and/or completely independent of the stimulus, and were mostly nouns or verbs. As a result of him learning the story quickly, the omissions and the additions occurred primarily in the earlier trials. These errors were spread throughout the segments of the story.

5.4.7.2 Analysis of GN's sequence

GN's scores (see Figure 5.14) suggest that there was not much of a difference in his performance between variables, although he scored lower for sequence than the other variables. Looking at the sessions in Tables 5.15 and 5.16 below, one can argue that sometimes the sequence was not completely maintained, due to additions and/or omissions. On three occasions he said his full name (Gabriele instead of Gabri), and once added his surname. Twice, he said 'Il Gabri', (this means 'the Gabri'); the addition of the article (il) before a person's name is an idiomatic feature that is used by people in Northern Italy.

With regard to the list of cities within the story, GN generally remembered the position of the first city (Cosenza), placing it incorrectly only twice; the sequential location of the last city was inaccurate four times. Conversely, the sequence of the second and third cities was always inaccurate. It seems that GN identified the list of the cities as a unit by itself, defining accurately the first and the last cities but making more mistakes in the middle of the list, demonstrating a primacy and recency effect.

Table 5.15 Examples of GN's sequence across all trials.

Stimulus	**c'era Gabri e il suo piano**	**Trial No.**	**No. of times**
Response	Gabriele al piano	1	1
	Gabriele Naretto al suo piano	2	1
	Gabriele al suo piano	4	1
	il Gabri	6	1
	il Gabri	9	1
Stimulus	**Luca e Gabri sono ok**		
Response	e Gabriele	1	1
		4	1
	il Gabri	6	1
Stimulus	**E rosa ballava se lui suonava**		
Response	Rosa Franciamore	1	1

Stimulus	**Fantastica mano**		
Response	magica mano	1	1
Stimulus	**Bravo bravo Gabri al piano**		
Response	bravi bravi tutti al piano	2	2
	bravo Gabriele al piano	4	1
	bravo il Gabri	5	1
		6	2
		9	1
		10	1
Stimulus	**e tutti le mani battevano**		
Response	e tutte	3	1
	battevano le mani	4	1
Stimulus	**Ottimo Gabri continua così**		
Response	ottimo Gabriele	2	1

Table 5.16 Examples of GN's sequence across all trials.

Stimulus	**a Cosenza, Milano, Torino, Pavia**	**Trial No.**	**No. of times**
Response	a Pavia, Cosenza, Milano, Torino	1	1
	a Cosenza, anche a Milano	1	1
	a Cosenza	2	1
	a Milano	2	1
	Cosenza, Gabri, Milano, Pavia	4	1
	Cosenza, Milano, Torino e Pavia	4	1
		4	1
		6	1
		7	2
		11	1
		8	1
		12	1
	a Cosenza a Milano a Torino e a Pavia	8	1
		11	1
		12	1
Stimulus	**la musica suonava a memoria**		
Response	la musica suonata	3	1
Stimulus	**bene Gabri magico al piano**		
Response	bene Gabriele	4	1
Stimulus	**Bello Gabri! Fantastica mano**		
Response	Gabri che fantastica mano	4	1

Stimulus	**Jazz studiava classica e pop**		
Response	e classica	8	1

5.4.8 LP's results for semantics, syntax, sonance and sequence over all trials

Figure 5.16 displays the scores achieved by LP for the entire story across all trials, differentiated by the four variables (semantics, syntax, sonance and sequence). LP achieved higher and similar results for semantics, syntax, and sonance. Although he attained lower scores in the sequence variable, this difference in score was fairly small. This could lead to the argument that LP processed semantics just as effectively as sonance. It could alternatively show that the task was too easy for LP. Section 5.4.10 discusses in detail the types of errors made by LP.

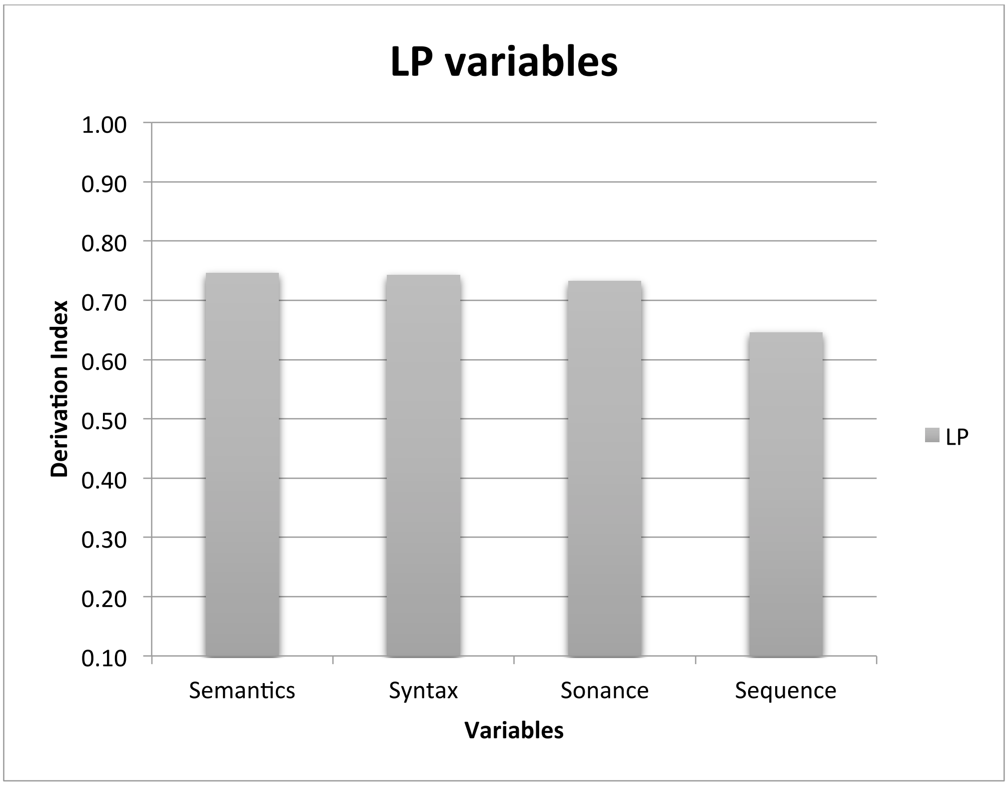


Fig. 5.16 LP's results per variable in over all trials.

5.4.9 LP's results for different segments over all trials

Figure 5.17 shows LP's results for the verbal memory experiment in each segment and per variable. Looking at the graph, LP achieved the highest scores in the first, second and third segments; this means that he recalled the first parts of the story better than the final two.

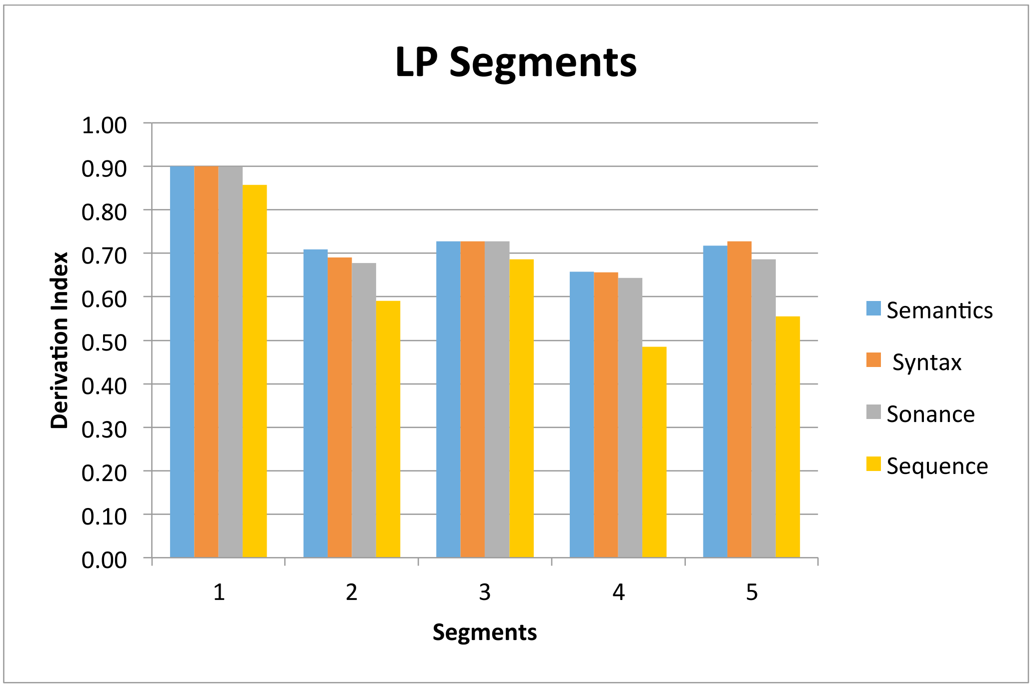


Fig. 5.17 LP's results per segment over all trials.

5.4.10 Qualitative analysis of LP's production across all the sessions

LP's response in the first session was brief but accurate, and over the course of the sessions his performance improved very rapidly, including the quantity of words; from the third session he repeated every segment correctly, with only a few minor errors, distributed throughout the trials. The first and the third segments seemed to be better remembered than the others, though the second and the fourth segments were also more accurate after the first session.

For the first three sessions there was a primacy but not a recency effect; the last segment was recalled with less accuracy than the first. The segments that were better recalled (in terms of length and accuracy) were the first and the third, which were the same; this suggests that LP identified the structure of the story, which may have been the main factor that enabled him to learn the stimulus within 11 sessions. The linguistic components were highly accurate in all sessions with just a few additions and omissions of words. He made errors in semantics; however on most occasions he used words that were close in meaning. Eleven of these errors were for nouns (e.g. 'Gabri' instead of 'Gabriele'), and 17 were adjectives or verbs that were incorrect but semantically related (e.g. 'ottimo', meaning 'excellent', instead of 'bravo', meaning 'good'). In the last five sessions he said 'lo spartito' (meaning 'musical score') instead of 'la musica' (meaning 'music'). LP recalled the sequence of the story accurately (and the list of locations) after only two sessions.

5.4.10.1 LP's omissions and additions (semantics, syntax and sonance errors)

Table 5.17 shows the number of times LP made omissions, repeated the stimulus in a correct way, the total number of words of the stimulus and the words he added:

Table 5.17 LP's word production across all sessions.

LP	TOTAL WORDS IN THE STIMULUS	WORDS CORRECTLY REPEATED	WORDS OMITTED	WORDS ADDED	TOTAL WORDS PRODUCED
Number	1,012	791	221	66	857
Derivation Index		0.78			
%			22%	8%	

There were complete or partial matches between the stimulus and response words 719 times; the total number of stimulus words across the 11 sessions was 1,012 (the total number of stimulus words was lower than for GN, as LP required fewer sessions to learn the story). The total number of words omitted was 221, a proportion of 22%. Omissions were concentrated in the middle segments (2,3 and 4), especially during the first three sessions, showing a primacy and recency effect. Omissions decreased as the sessions progressed.

LP added 66 words that were either present, partially linked or not present in the stimulus, which means that 8% of the total production (857) were added words. These were mainly redundant nouns or verbs, which were semantically related to the words in the stimulus, and often repeated more than once.

5.4.10.2 Analysis of LP's sequence

LP's score for sequence was lower than the other variables, as he made errors such as text inversions and also additions and/or omissions. Nevertheless sequence was maintained most of the time (see Tables 5.18 and 5.19), although sometimes he substituted the word of the stimulus with a synonym. For example, for 'fantastica mano' (meaning 'fantastic hand') LP was able to maintain the absolute sequence through saying 'mirabile mano' (meaning 'admirable hand') and 'formidabile mano' (meaning 'amazing hand'). For 'leggeva la musica' ('reading the music') LP substituted 'leggeva lo spartito' ('reading sheet music'). He understood the gist of the story, but he did not remember the precise words so used alternatives with similar meanings.

With regard to the list of cities, the last one (Pavia) seemed to be salient for him, as on four occasions he put it in the correct place compared to the placement of the other cities.

Table 5.18 Examples of LP's sequence across all trials.

Stimulus	**bravo bravo Gabri al piano**	**Trial No.**	**No. of times**
Response	bravo Gabriele	1	1
Stimulus	**Luca e Gabri sono ok**		
Response	Gabri e Luca sono ok	3	1
Stimulus	**Rosa ballava se lui suonava**		
Response	ballava quando lui cantava	1	1
	mentre Gabri suonava	4	1
Stimulus	**Una volta tempo fa c'era Gabri**		
Response	C'era una volta Gabri	2	1
Stimulus	**Jazz studiava, classica e pop**		

Response	Classica al Jazz al Rock al pop	2	1
	Classica studiava, jazz e pop		
	Jazz suonava	8	1
		10	1
Stimulus	**Fantastica mano**		
Response	mirabile mano	2	1
	formidabile mano	4	1
		10	1

Table 5.19 LP's sequence.

Stimulus	**Cosenza, Milano, Torino, Pavia**	**Trial No.**	**No. of times**
Response	Cosenza, Milano, Pavia	1	1
	Torino, Cosenza, Pavia, Milano	2	1
	Torino, Milano, Pavia	4	1
		6	1
	Cosenza, Torino, Milano, Pavia	5	1
	Milano, Torino, Cosenza, Pavia	6	1
Stimulus	**Ottimo Gabri continua così**		
Response	bravo Gabri	6	1
Stimulus	**Bene Gabri magico al piano**		
Response	Bravo Gabri grande al piano	6	1
	bravo al piano	8	1
Stimulus	**Leggeva la musica**		
Response	leggeva lo spartito	7	1
		9	1
		10	1
		11	1

5.4.11 AN's results for semantics, syntax, sonance and sequence over all trials

Figure 5.18 displays the scores achieved by AN for the story, which were the highest of all participants. His scores for semantics, syntax, and sonance were broadly similar, however he attained a slightly lower score for sequence, although this difference was fairly small. This suggests that AN, like the other participants, processed semantics just as effectively as sonance. Similar achievements in the diverse variables could indicate that the task was too simple for AN.

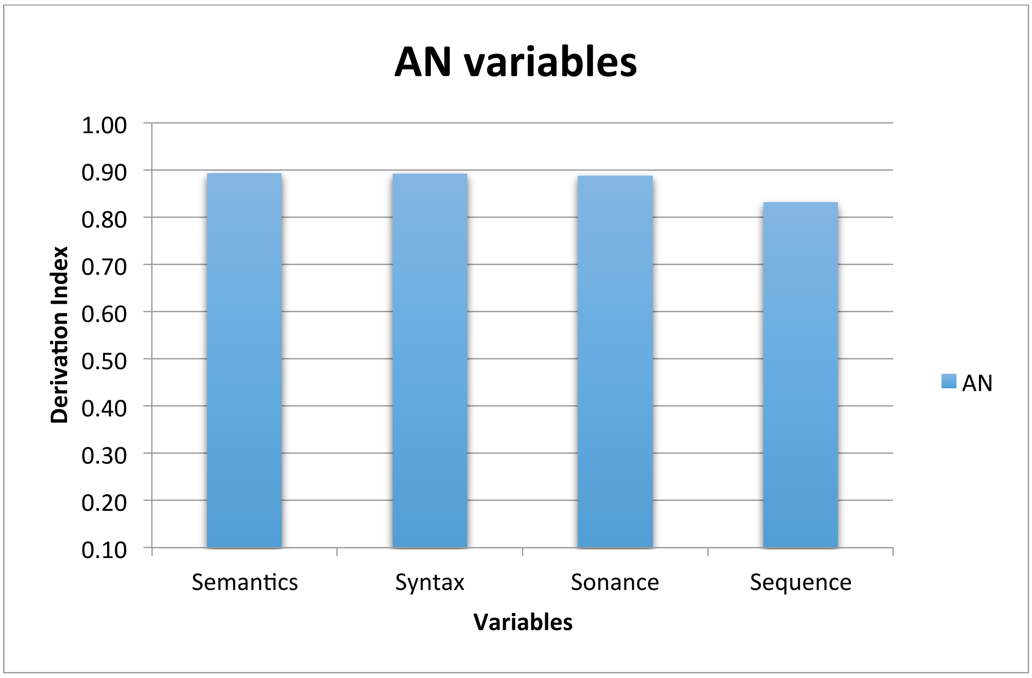


Fig. 5.18 AN's results per variable over all trials.

5.4.12 AN's results for different segments over all trials

Figure 5.19 displays AN's scores in the verbal memory experiment in each segment and per variable. AN attained the highest scores in the first, third and fifth segments; this means that he recalled the beginning, part of the middle and the end of the story better.

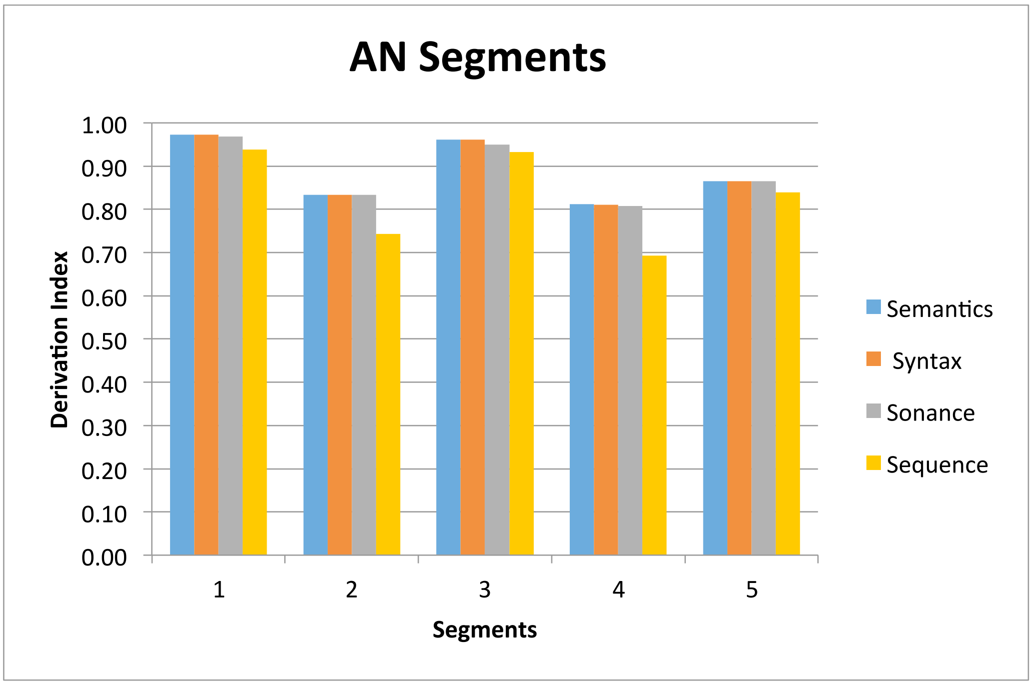


Fig. 5.19 AN's results per segment over all trials.

5.4.13 Qualitative analysis of AN's across all the sessions

Throughout the sessions AN's responses were largely accurate; he did not omit whole segments, only a few words within them. On some occasions he remembered parts of sentences, for example saying 'magical something' instead of 'magical music man' or 'somewhere' instead of 'Wimbledon'. He also got the linguistic components correct, in both production and sequence. AN learned the whole story accurately in 13 sessions; he made 12 semantic errors pertaining to nouns and pronouns (e.g. 'he' for 'who', 'guy' for 'young man', 'Los Angeles' for 'Las Vegas'), one syntactic error ('played' for 'play') and one verb was substituted for another which was semantically related ('liked' for 'loved).

5.4.13.1 AN's omissions and additions (semantics, syntax and sonance errors)

Table 5.20 shows the number of times AN made omissions, repeated the stimulus in a correct way, the total number of words of the stimulus and the words he added:

Table 5.20 AN's word production across all sessions.

AN	TOTAL WORDS IN THE STIMULUS	WORDS CORRECTLY REPEATED	WORDS OMITTED	WORDS ADDED	TOTAL WORDS PRODUCED
Number	1,014	916	98	7	923
Derivation Index		0.90			
%			10%	0.7%	

Across all trials, on 916 occasions there were complete or partial word matches between stimulus and response out of a possible total of 1,014. The total number of words omitted by AN was 98, a proportion of 10%. Omissions were noted from the lists of locations in segments 2 and 4, and in several sessions he omitted 'good old Derek' from the last segment; it is possible to detect a weak primacy and recency effect.

Throughout the 13 sessions AN added seven words (hence, the percentage of additions was less than 1%). Most of these were already present in the stimulus (he repeated the word 'and' five times); one was not, though was related to the stimulus ('was' instead of 'is').

5.4.13.2 Analysis of AN's sequence

AN's sequence score was lower than the other variables, although like LP, he made fewer errors compared to the savants. Tables 5.21 and 5.22 show that, on occasion, the sequence was not completely maintained due to additions and/or omissions. Table 5.22 shows that AN was not always able to remember the correct list of locations in sections 2 and 4, and he sometimes substituted one of them with another city which sounded similar, such as 'Roehampton' instead of 'Redhill'. The use of 'somewhere' instead of the appropriate name of the city (in trials 2 and 10) shows that he remembered that there was another location in the sequence, however the precise name was not stored in his working memory.

Table 5.21 Examples of AN's sequence across all trials.

Stimulus	**a young man called Derek**	**Trial No.**	**No. of times**
Response	a guy a man	1	1
Stimulus	**who loved to play the piano**		
Response	he loved to	2	1
		3	1
		4	1
		8	2
	who liked	12	1

Table 5.22 Examples of AN's sequence across all trials.

Stimulus	**In London and Las Vegas, and Redhill and Ramsgate- In Warfield and Wimbledon, and Holland and Hollywood**	**Trial No.**	**No. of times**
Response	in Wimbledon	1	1
	in London and Los Angeles-in Wimbledon and Somewhere	2	1
	in Hollywood, Wimbledon and Holland	5	1
	In Warfield, Wimbledon	6	1
	In London, Las Vegas, Redhill	9	1
	in London and Las Vegas and Roehampton - In Hollywood and Holland and Somewhere	10	1
	In Holland and Hollywood	11	1
	In Hollywood and Holland	12	1

5.5 Discussion

5.5.1 Participants' results for semantics, syntax, sonance and sequence

The graph below (Figure 5.20) illustrates the results that each participant obtained for each variable. DP achieved the lowest score for all variables. AN achieved the highest scores throughout the variables, closely followed by GN, who performed almost as well as AN along the variables. LP performed quite consistently across the sessions. However he did not reach the same level as AN or GN in any of the variables.

Each participant scored consistently for the first three variables (semantics, syntax and sonance) but obtained lower scores for sequence.

This could suggest that the first three variables were interdependent; however, there was an indication that sequence appeared to be independent from the others.

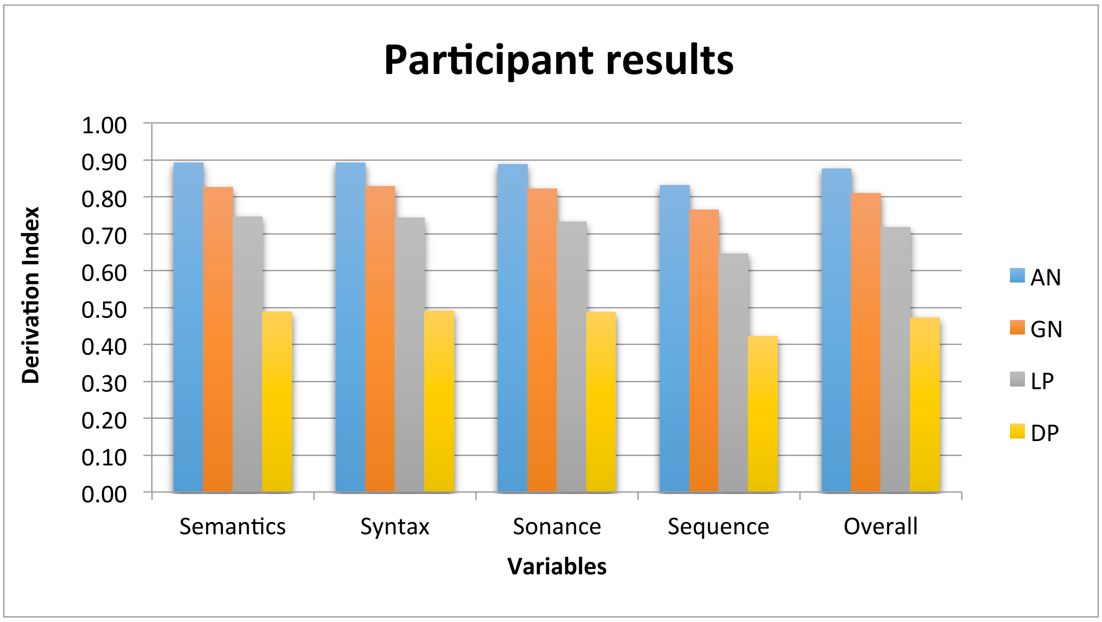


Fig. 5.20 Participants' results per variable over all trials.

5.5.2 Participants' results for different segments

The chart below (Figure 5.21) shows all the participants' scores in the verbal memory experiment per segment.

Collectively, the participants achieved their highest scores in the first and last segments; this means that they had a better recollection of the beginning and the end the story. They all obtained lower scores for segments two and four, with the exception of DP, whose lowest score was for the third segment. Primacy and recency effects, were very evident in DP's performance, and a general primacy and occasional recency effect was noted for the other participants.

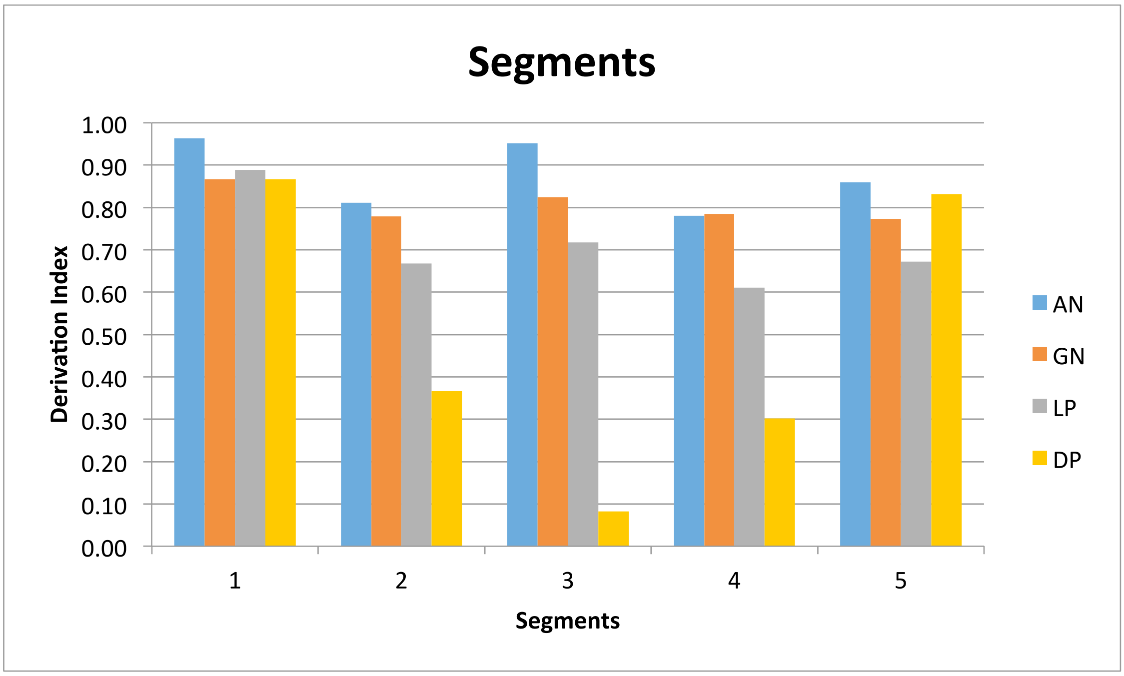


Fig. 5.21 Participants' results per segment over all trials.

5.5.3 Participants' scores from all trials

The following graph (Figure 5.22) displays each participant's scores across the complete experiment. The gaps shown in the graphs indicate the time between sessions (between sessions 9 and 10, there was a one month gap; from 19 to 20 three months; 21 to 22 six months; 23 to 24 one year, and from 25 to 26 a two year gap).

Each subject progressed differently from one session to the next. At the beginning, DP, who completed 27 sessions, consistently obtained the lowest score from the third session onwards, with some minor variations in the actual score achieved. LP scored the lowest, followed by GN, DP and AN. However, as the experiment progressed, LP's scores improved gradually (with some variations), and he obtained a very high score in his final trial. GN scored the lowest of all participants in the second session, but from the third session his scores improved greatly, and he maintained high scores with little variation for the remainder of the experiment. AN maintained fairly high scores bar some minor variations compared to the other participants throughout the experiment.

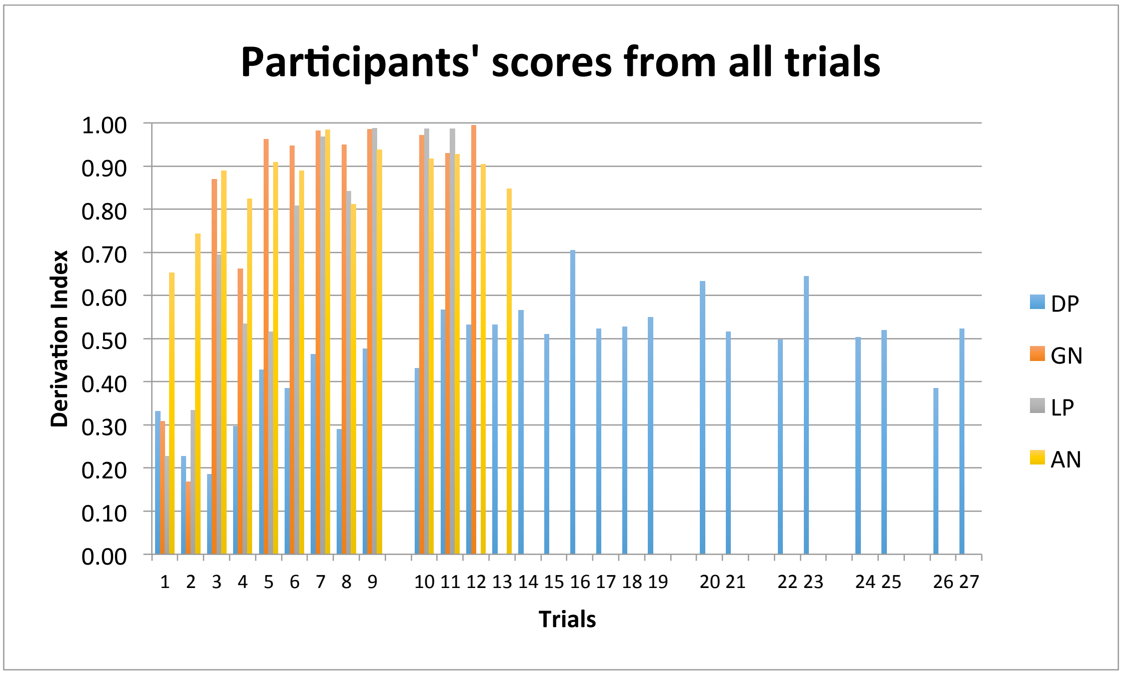


Fig. 5.22 Participants' scores from all trials.

5.5.4 Participants' results from trials testing long-term memory and trials testing a combination of long-term and working memory

The verbal experiment was designed to test participants' long-term memory (LTM), as well as the combination of LTM and working memory (WM). Apart from the first session (in which participants were introduced to the stimuli, asked to repeat it and exposed to the stimuli again) all sessions comprised two trials. In the first, the participants were asked what they could recall of the stimulus from the previous sessions (LTM). They were then played the stimulus and asked to repeat it again in the second trial (combination between WM and LTM).

Figures 5.23 to 5.26 below show the differences in scores between LTM and a combination of LTM and WM in each session for each participant. The gaps between bars indicate the timing of the sessions (between the 5th to the 6th there was a month's gap, from 10th to the 11th three-months, from the 11th to the 12th six months, from the 12th to the 13th one year and from the 13th to the 14th two years gap).

DP's chart (Figure 5.23) shows that on 8 occasions out of 14 he scored higher for the combination of LTM and WM compared to LTM. However, this was not the case for the ninth session, where his combination of LTM and WM score was low across all of his sessions. It seems he had difficulties with the consolidation of both LTM and WM. So about 1 in 3 times, DP's combination of LTM and WM was worse than his LTM. The extraordinary thing is that DP (unlike the others) became worse when LTM and WM were combined. This suggests some form of conflict between the two.

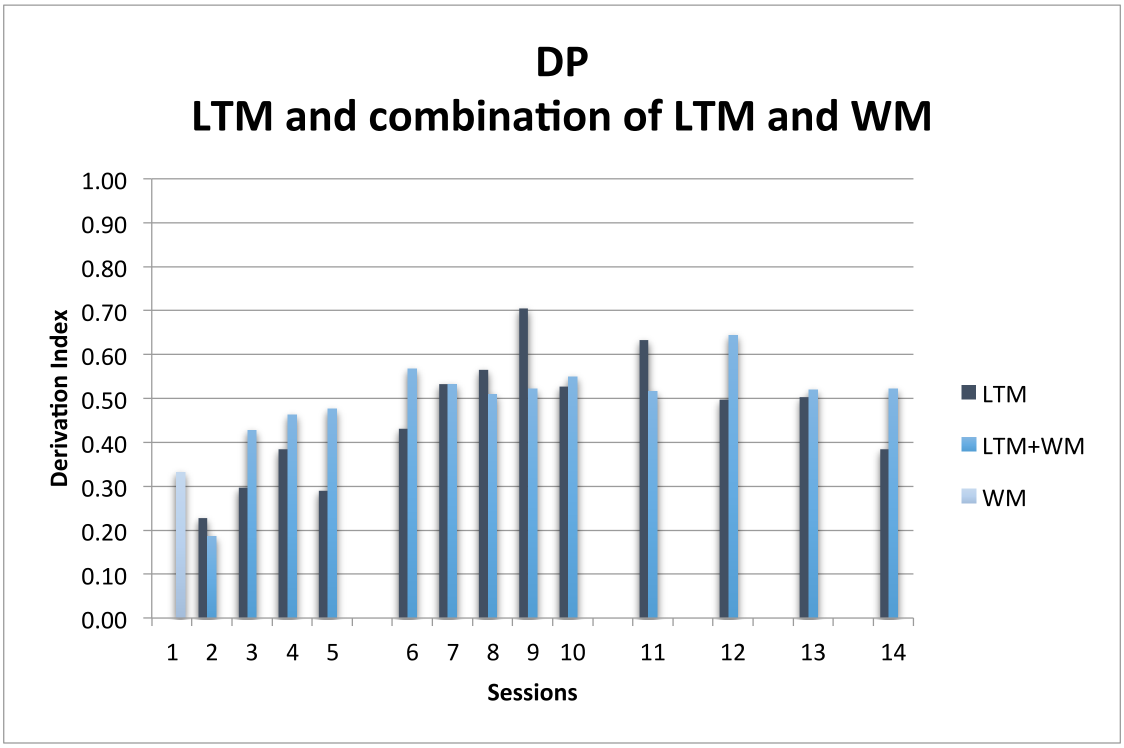


Fig. 5.23 DP's scores for long-term and the combination of long-term and working memory across 14 sessions.

GN's results (Figure 5.24) show that he scored more highly for the combination of LTM and WM than LTM in five trials out of seven; this would indicate that GN was reliant in both forms of memory. However, there were only minor differences between WM and LTM scores in sessions four, five and six. During session seven he did not attempt a WM performance as he had learned the story and did not wish to listen to and repeat it again. Even with a gap of three months between sessions five and six, there were no indications of decreased LTM performance. GN's results demonstrated a learning profile much more predictable then DP, showing an increasing learning over time.

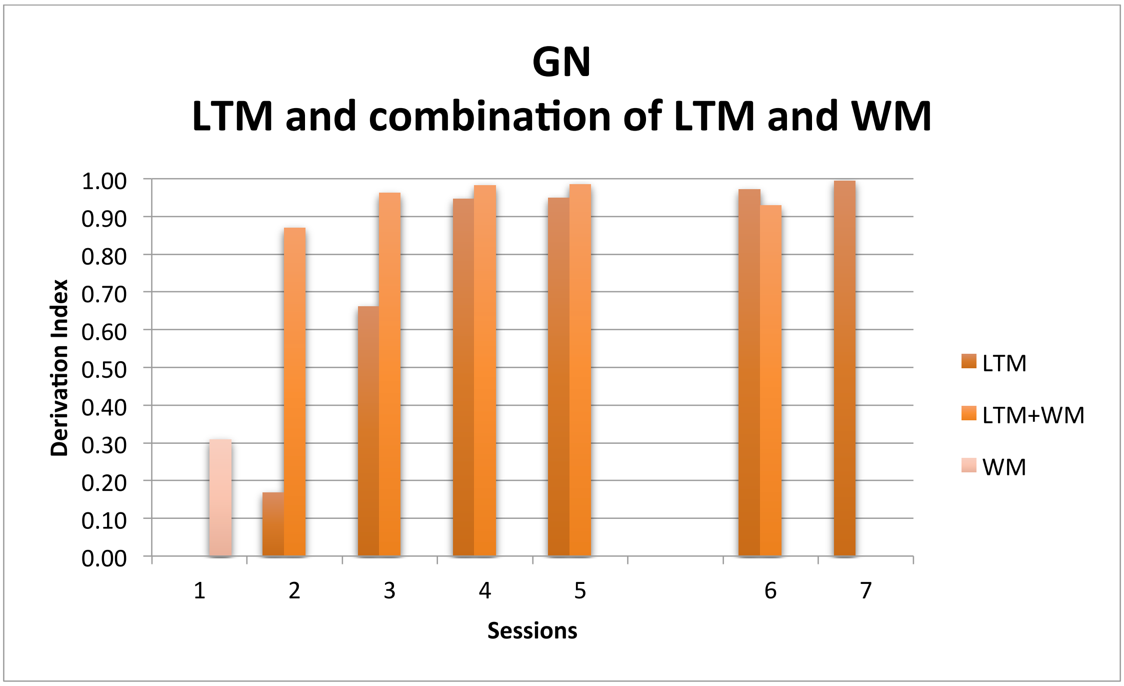


Fig. 5.24 GN's scores for long-term and the combination of long-term and working memory across 7 sessions.

LP's results (see Figure 5.25) show a higher score for WM than for the combination of WM and LTM in half of the sessions; the remaining sessions which contained both types of trial (third and sixth) gave very similar scores for both types of memory. After a one-month gap (session five to six), an improvement in LTM meant that scores became equivalent to the WM trials, and suggesting that LP had learnt the story.

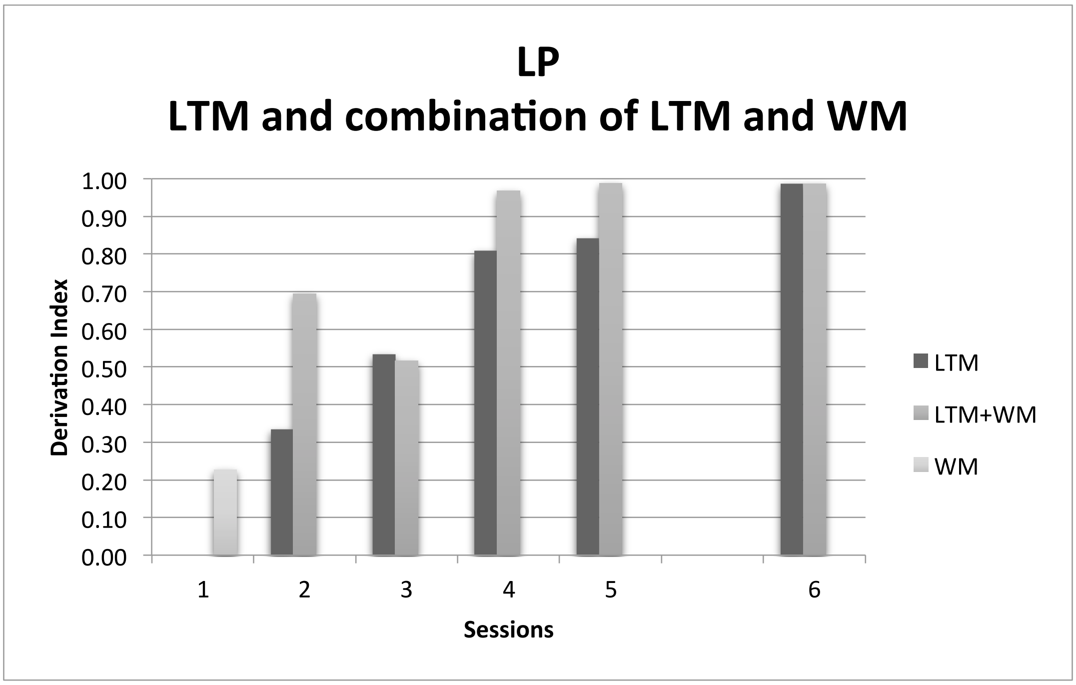


Fig. 5.25 LP's scores for long-term and the combination of long-term and working memory across 6 sessions.

AN scored more highly for WM five times out of six as expected (see Figure 5.26), and by the last session WM and LTM were almost the same as he had learned the story.

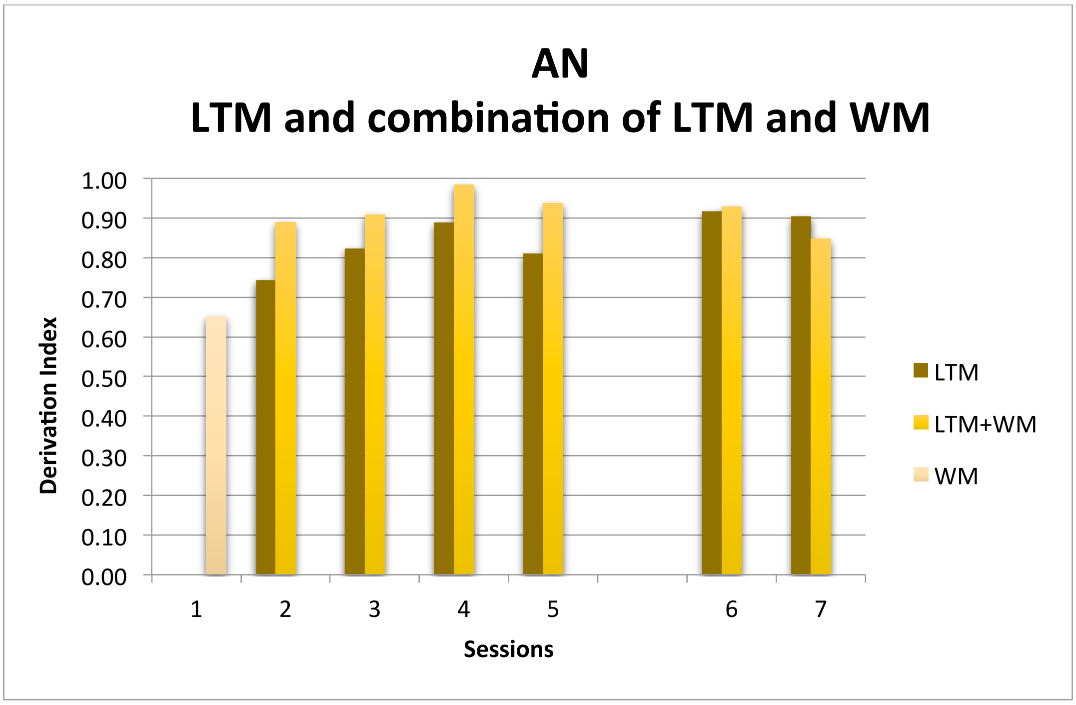


Fig. 5.26 AN's scores for long-term and the combination of long-term and working memory across 7 sessions.

To conclude, all the participants, with the exception of DP, exhibited comparable patterns of recollection, increasing the accuracy of their performances as the trials progressed (although at varying levels). This suggests similar learning processes. However, DP demonstrated a fluctuating pattern in his learning. All of the participants exhibited higher results for WM than LTM.

5.5.5 Comparing DP with GN

Figure 5.27 displays the average scores (in relation to each of the four variables) obtained by DP and GN on the verbal memory test. On average, GN obtained higher scores than DP, but his results displayed a similar trend with regard to differences between the variables (suggesting that DP and GN were performing similarly but at a different overall level). DP's performance was considerably lower than GN's, and it is difficult to think why, as it appeared that DP understands the story (and the meanings of the words within it). The prediction that DP would score higher on sonance (and perhaps sequence) than semantics and sequence was not found to be true. On the contrary, the reverse is the case. It seems that, as the words in the story were all easily comprehensible by DP (as shown for example, through his occasional use of synonyms) his 'music processing module' was not brought into play. It seems that he found the task difficult not on amount of memory, but as an artefact of verbal learning and recall. We can hypothesise that (see Figure 5.3) had the task been more semantically complex (i.e. using words that DP did not understand) his music processing module may have been 'kick started', and he may have performed at a high level. An anecdotal example of this is DP's capacity to learn the words of songs in foreign language with apparent ease.

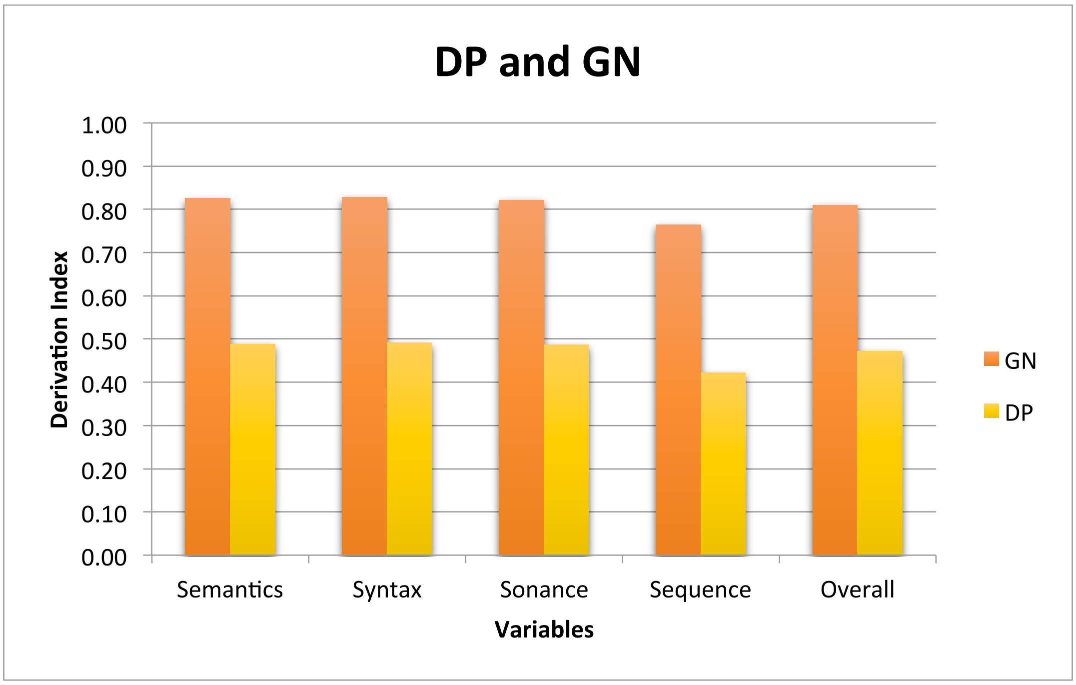


Fig. 5.27 DP and GN's results per variable in over all trials.

The following graph (Figure 5.28) shows the differences in average scores obtained by DP and GN for each segment of the story. In the first and last segments, they performed at a similar level, but in the second, third and fourth, DP's scores were considerably lower, whilst GN continued to perform at the same level. This can be attributed to a primacy and recency effect for DP. It suggests that GN comprehended the structure of the story (as the first segment was the same as the third), and that DP did not.

Research into recency and primacy effects has shown that listeners asked to remember a list of items will tend to remember the first two and last two items (Postman and Phillips, 1965), However, given a list in which the third item is the same as the first, there is a high probability that this item will also be remembered accurately. DP did not demonstrate this effect in this experiment (he did not remember the third segment as well as the first, even though they are equivalent). This suggests that, rather than there simply being a primacy and/or recency effect, DP failed to detect the structure of the stimulus.

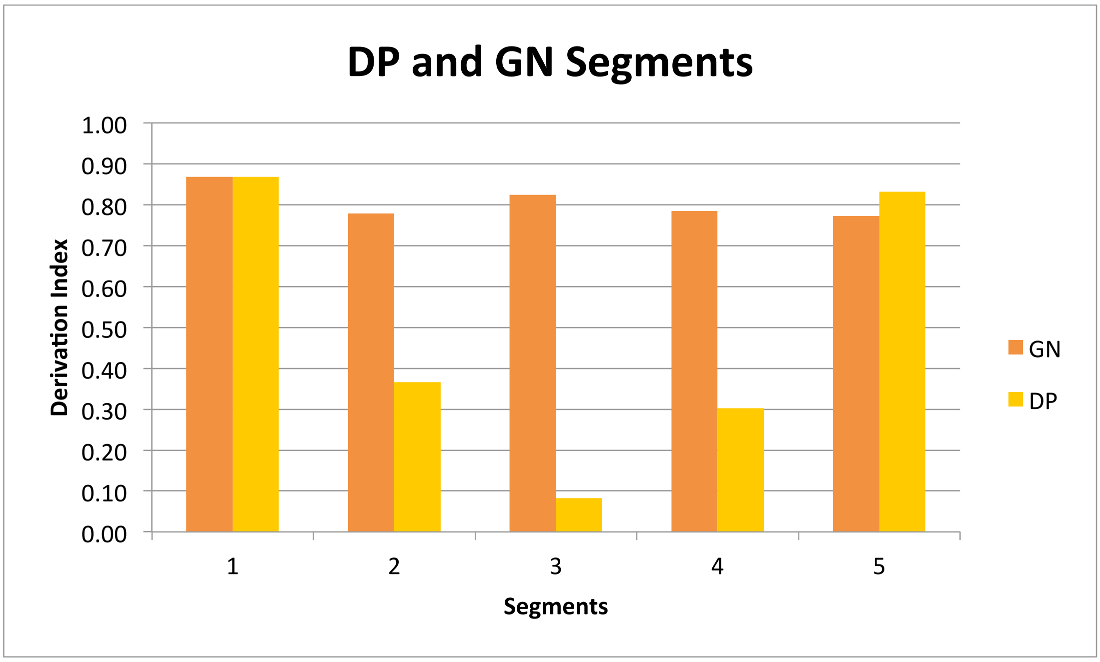


Fig. 5.28 DP and GN's results per segment in over all trials.

Figure 5.29 displays the score differences between DP and GN. DP outperformed GN in the first two trials; thereafter GN outperformed DP.

DP participated in 27 sessions; GN only completed 12, as he did not wish to carry on with the experiment after this point.

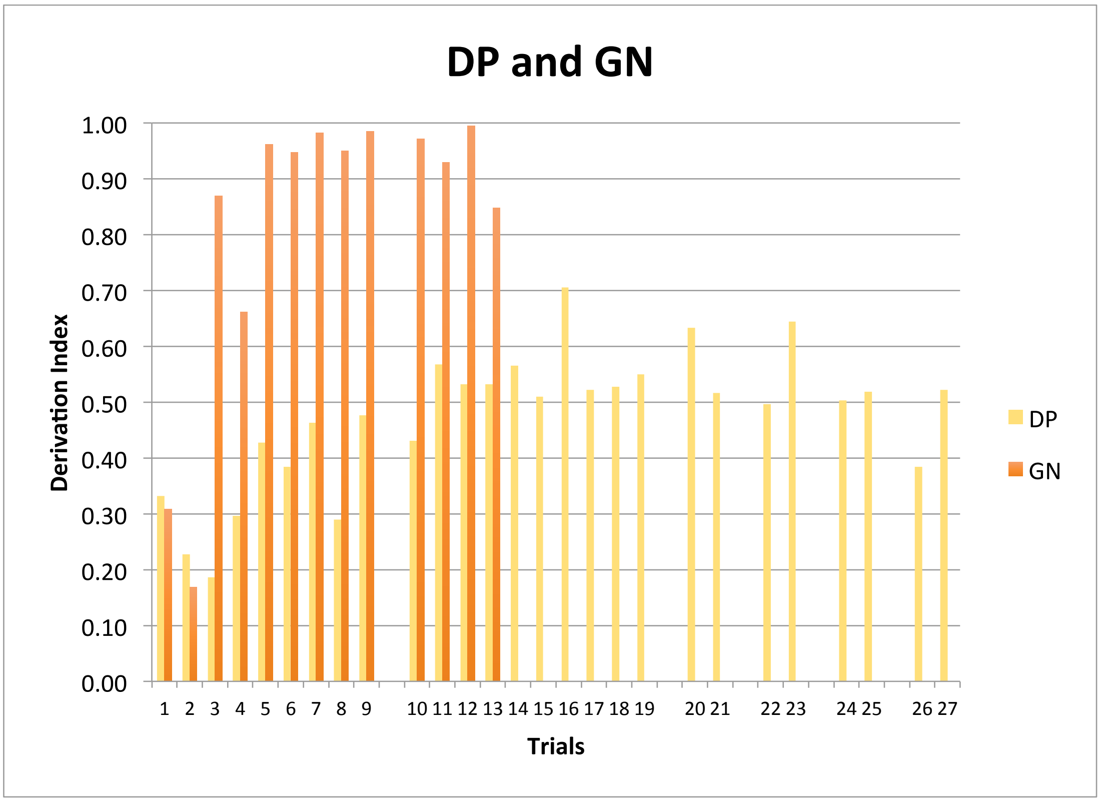


Fig. 5.29 DP and GN's results per trial.

5.5.6 Comparing savants' and non-savants' results

The four subjects each participated in a different number of trials, hence for comparison purposes only the first 11 sessions of each participant were used (the lowest total number of trials completed by any one participant).

Comparing DP's and AN's responses there was a clear difference in the number of omissions and additions; DP omitted 487 words and added 66 over his first 11 sessions, whereas AN omitted 92 and added 7. Most of the additions were connecting words, such as 'and' or 'then'. DP added words that were related to the stimulus, and several that were completely unrelated. This did not occur with AN, as the majority of his additions were present in the stimulus; on one occasion the word was not an exact match but was still related. Table 5.23 shows DP and AN's word production in the 11 sessions.

Table 5.23 DP and AN's word production per 11 sessions.

PARTICIPANTS	TOTAL WORDS IN THE STIMULUS	WORDS CORRECTLY REPEATED		WORDS OMITTED		WORDS ADDED		TOTAL WORDS PRODUCED
	Number	Number	DI	Number	%	Number	%	Number
DP	858	371	0.43	487	57	66	15	437
AN	858	766	0.89	92	11	7	1	773

Comparing GN's and LP's responses shows a slight difference in the number of words omitted (see Table 5.24); GN omitted 166 words over 11 sessions, whereas LP omitted 222. GN added 218 words, whilst LP added 66. Qualitative analysis of the data shows the additions that GN and LP made were mainly adjectives and nouns rather than connecting words, but while LP added words that were present in the story, GN added many words that were completely different from the stimulus. This could suggest that LP was more focused on the task compared to GN, who sometimes became distracted.

Table 5.24 GN and LP's word production across 11 sessions.

PARTICIPANTS	TOTAL WORDS IN THE STIMULUS	WORDS CORRECTLY REPEATED		WORDS OMITTED		WORDS ADDED		TOTAL WORDS PRODUCED
	Number	Number	DI	Number	%	Number	%	Number
GN	1012	846	0.84	166	16	218	20	1064
LP	1012	790	0.78	222	22	66	8	856

Overall, the additions and omissions in DP and GN's responses differed considerably at a quantitative level. DP made 487 omissions over 11 sessions (see Table 5.24), whilst GN made 166. DP made the same number of additions as LP (66 words), whilst GN added 218 words.

At a qualitative level, both DP and GN added words not taken from the stimulus; GN did this more than DP. Both participants made these additions during the first few sessions but not thereafter. The comparison participants did not make this type of error (instead adding words taken from elsewhere in the stimulus);

this could suggest that they were more focused on the task, and were considerably trying to do well (contrasted to the intuitive approach of DP and perhaps GN).

DP made the highest number of omissions followed by LP, GN and AN; with regard to additions, GN made the highest number followed by LP, DP and AN. At the end of the sessions GN, LP and AN had, to all intents and purposes, learned the story (this was one of the reasons why the data gathering sessions were concluded earlier than DP); although DP completed 27 sessions, he did not learn the story fully.

Table 5.25 and Figure 5.30 display~~s~~ the average word production per session for all the participants. For each, the total numbers of words produced, added and omitted in the first 11 sessions were divided by 11 to obtain averages per session.

Table 5.25 All participants' average word production per session.

PARTICIPANTS	TOTAL WORDS IN THE STIMULUS	WORDS CORRECTLY REPEATED		WORDS OMITTED		WORDS ADDED		TOTAL WORDS PRODUCED
	Number	Number	DI	Number	%	Number	%	Number
DP	78	33.73	0.43	44.27	57	6	15	40
AN	78	69.64	0.89	8.36	11	0.64	1	70
GN	92	76.91	0.84	15.09	16	19.82	20	97
LP	92	71.82	0.78	20.18	22	6	8	78

As the graph shows, DP made more omissions than the other participants, leaving out almost half the stimulus (on average), whereas LP omitted around 20%, followed by GN around 16% and AN around 9%. The number of additions seems very similar, although GN omitted more words than the other participants. AN completed the task most accurately, followed by GN, LP and DP.

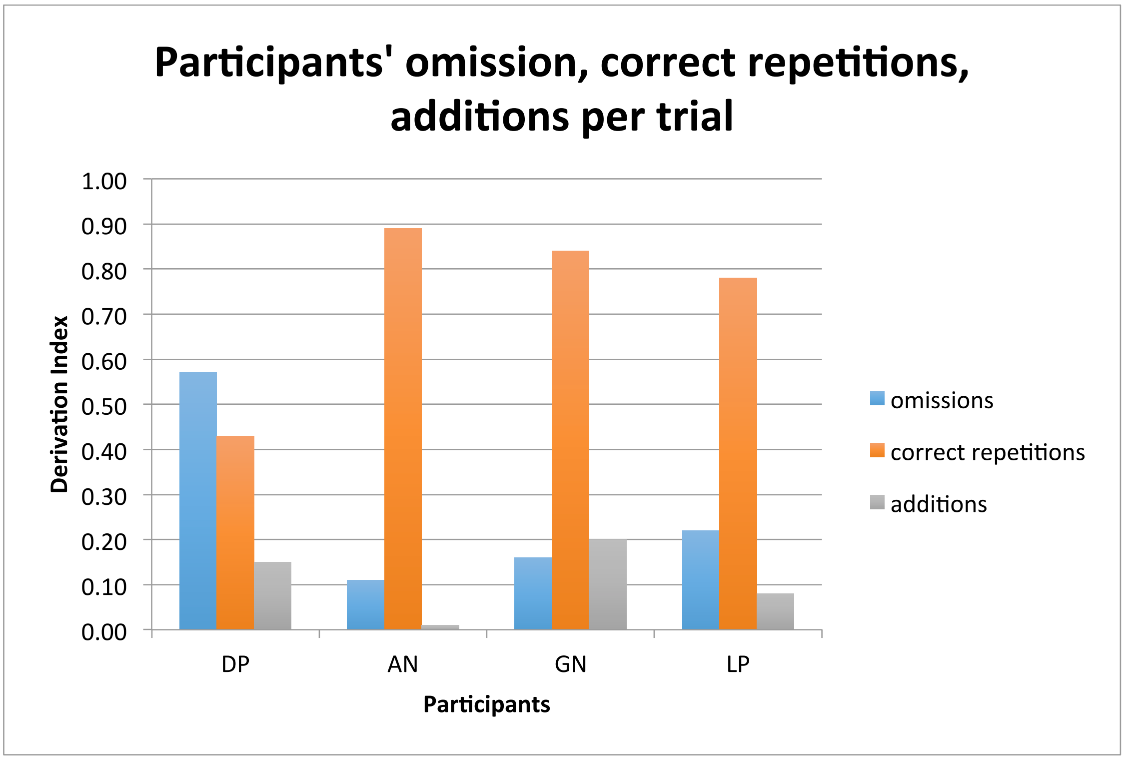


Fig. 5.30 All participants' average words production, additions and omissions per trial.

5.5.7 Participants' results over all trials, comparing their response for each trial with both the stimulus and the previous trial

Another focus of analysis was a comparison of the data for each participant against their responses in the previous trial, rather than the stimulus. The aim of this method was to ascertain if the participants were more inclined to copy their previous recollections, or the original stimulus. The analyses below are for each participant, per variable and per segment, and begin from the second session to allow comparison with participants' prior responses. The gaps shown in the graphs below (from Figures 5.31 to 5.37) indicate the timetabling of sessions (between sessions 9 and 10, there was a one month gap; between 19 and 20 three months; 21 and 22 six months; 23 and 24 one year, and from 25 to 26 a two year gap).

5.5.7.1 Participants' results for semantics, syntax, sonance and sequence, comparing their responses for each trial with both the stimulus and the previous trial

Figure 5.31 shows that all the participants except GN achieved higher scores when the data were compared to their previous responses, rather than the stimulus.

Of note was a consistent pattern of results between the variables. Within each analysis (between trials, and with the stimulus) each participant scored similarly for semantics, syntax and sonance (though these scores varied by participant and type of analysis), but scored lower for sequence.

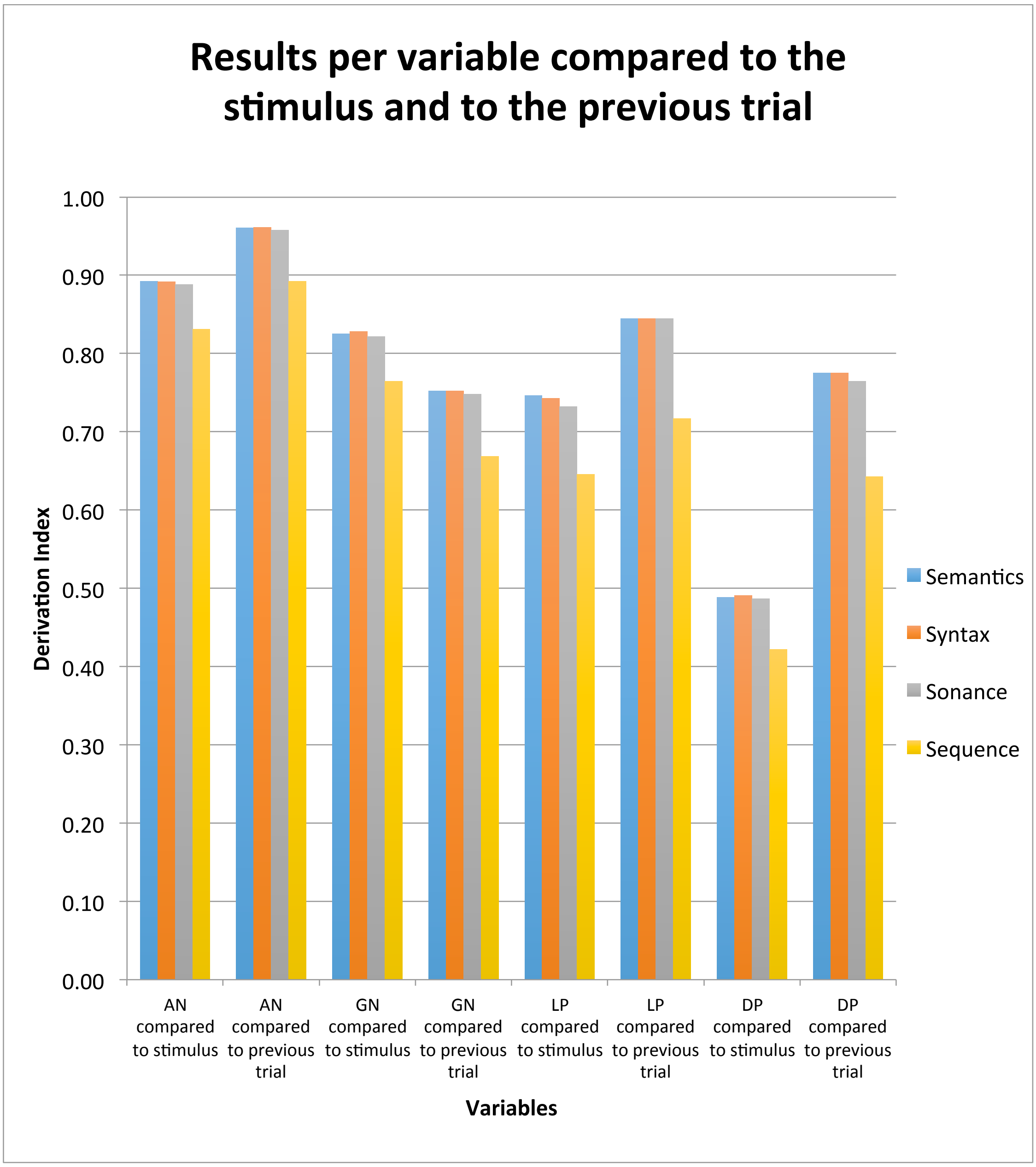


Fig. 5.31 Participants' results for over all trials, per variable compared to the stimulus and to the previous trial.

5.5.7.2 Participants' results for each segment comparing their responses for each trial with both the stimulus and the previous trial

Figure 5.32 shows that, when his responses were compared against the stimulus, AN achieved his highest results in the first, third and fifth segments, whereas when compared to the previous sessions, he achieved high results in the first, second, fourth and fifth segments. GN's responses demonstrated a similar pattern when compared to the stimulus and to the previous sessions, with the exception of the fourth and fifth segments; when compared against the stimulus, he performed slightly better in the fourth segment than the fifth, whereas the opposite was true when his responses were compared to the data from the previous trial. LP produced a similar pattern in both analyses with the exception of the fourth and fifth segments, for which he achieved slightly higher results when his responses were compared to the previous session. For both types of analysis, DP scored most highly in the first and fifth segments, with much lower results for the middle segments.

In general, the graph shows fluctuating results between segments; overall the participants' scores decreased from the first to the second segment, both compared to the stimulus and to the previous trial. DP and AN's scores decreased further between the second and third segments, when considered in relation to their previous responses, whereas GN and LP's scores increased between these two segments, with all participants bar LP scoring higher for the final segment.

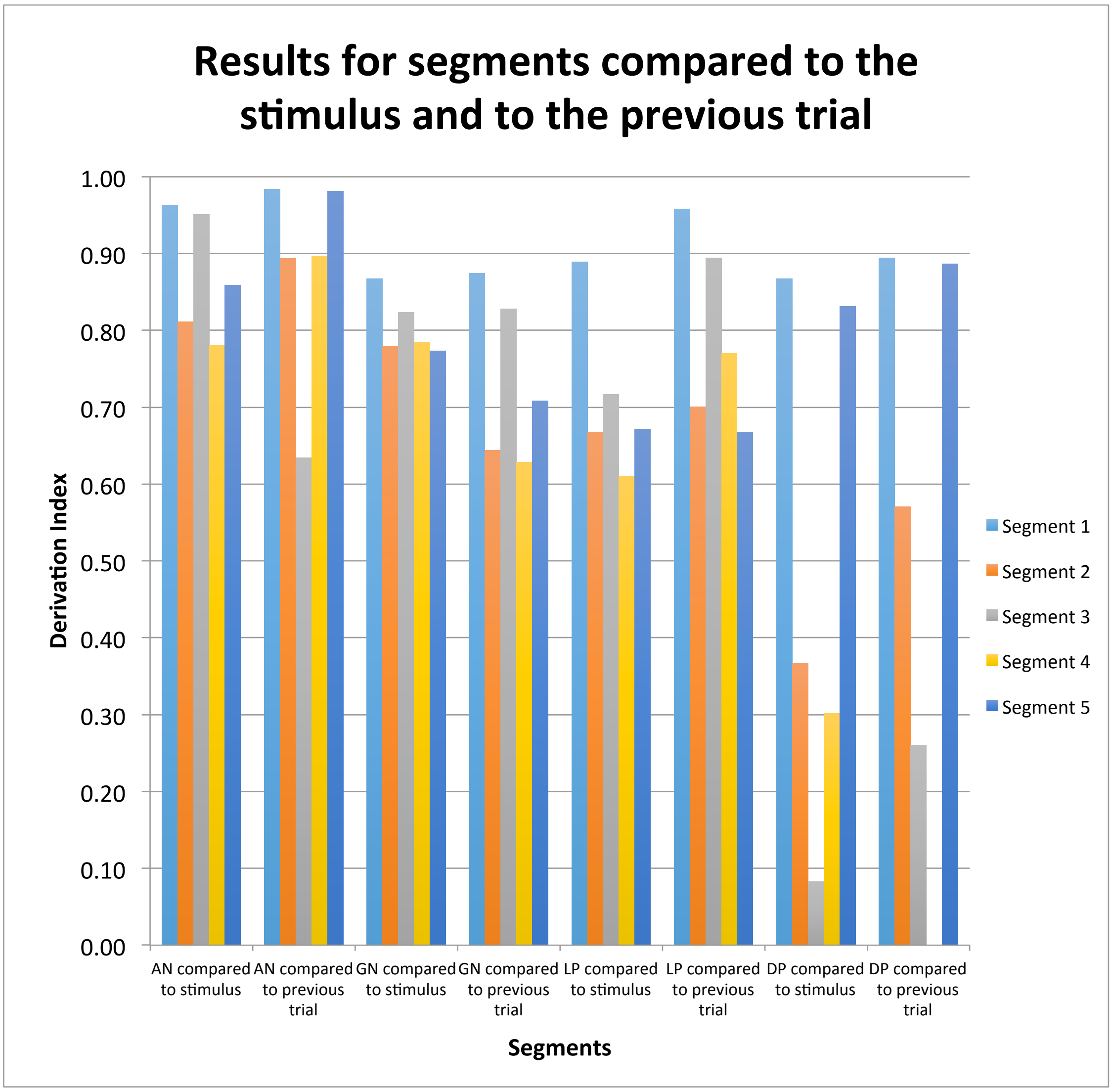


Fig. 5.32 Participants' results for over all trials, per segment compared to the stimulus and to the previous trial.

5.5.7.3 Participants' results for all the trials, comparing their responses for each trial with both the stimulus and the previous trial

The chart below (Figure 5.33) displays the underlying trend of DP's performances; his scores improved quite rapidly at the beginning (during the first seven trials) but this trend slowed, and then his scores started to deteriorate. Throughout the trials, DP achieved higher scores when his performance was compared to his own responses from previous trial rather than the stimulus. However, his scores for the two different types of analysis increased and decreased in parallel. Therefore, on the days that he found it easier to remember his most recent attempt at the task, he was best able to remember the stimulus, and vice versa. Even though the stimulus was repeated during every session, his recollection of his own version of the story was stronger; even on the occasions where it appears that his memory was weaker, his responses were more in line with the previous session than the stimulus itself. Consequently, it seems that DP formed an internal representation of the stimulus which was stronger than the external. The significance of these findings will become apparent when we compare then data to those pertaining to DP's musical memory in chapter 6.

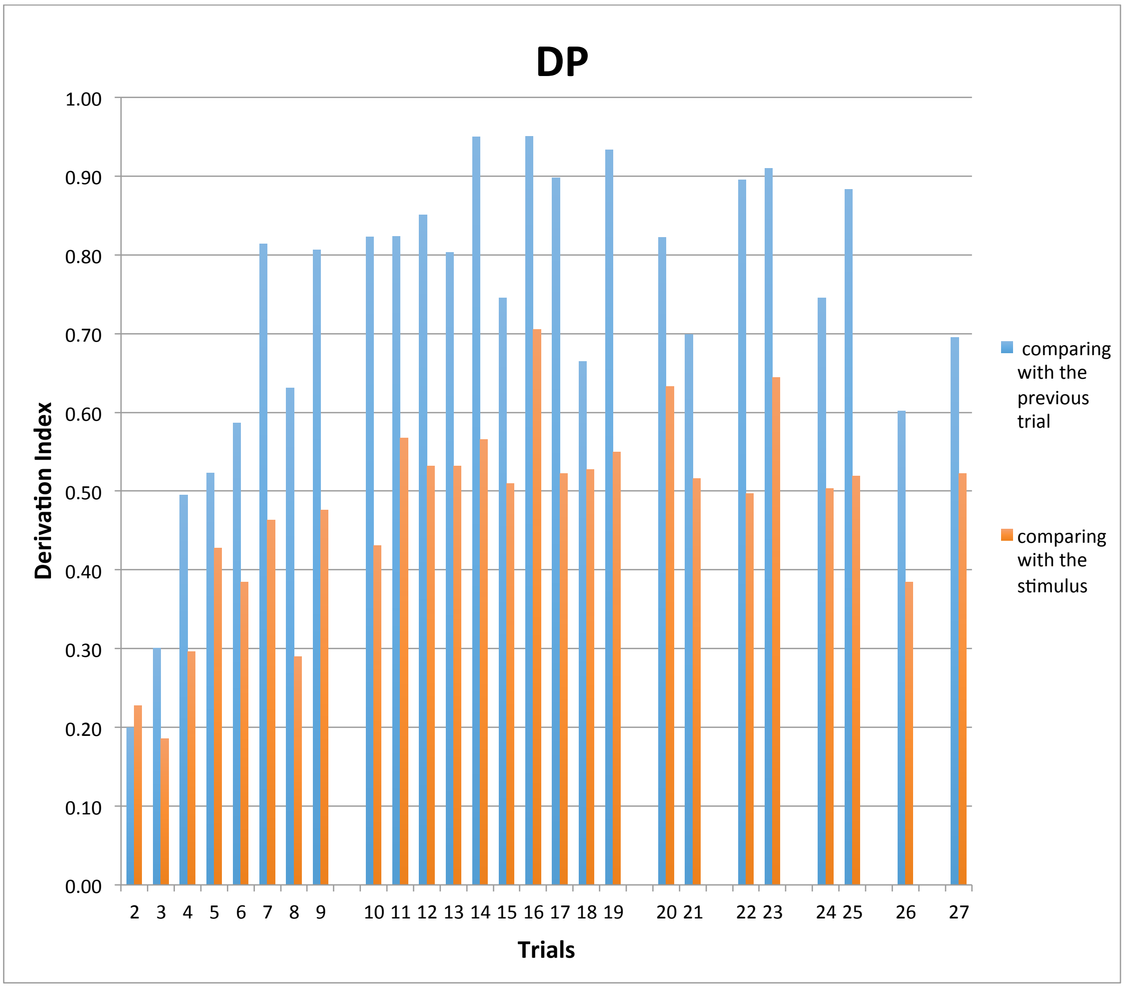


Fig. 5.33 DP's results for over all trials, comparing his responses with both the stimulus and the previous trial.

The graph below (see Figure 5.34) indicates that there was a correlation between both sets of results; hence it would appear that one could be seen as a predictor of the other.

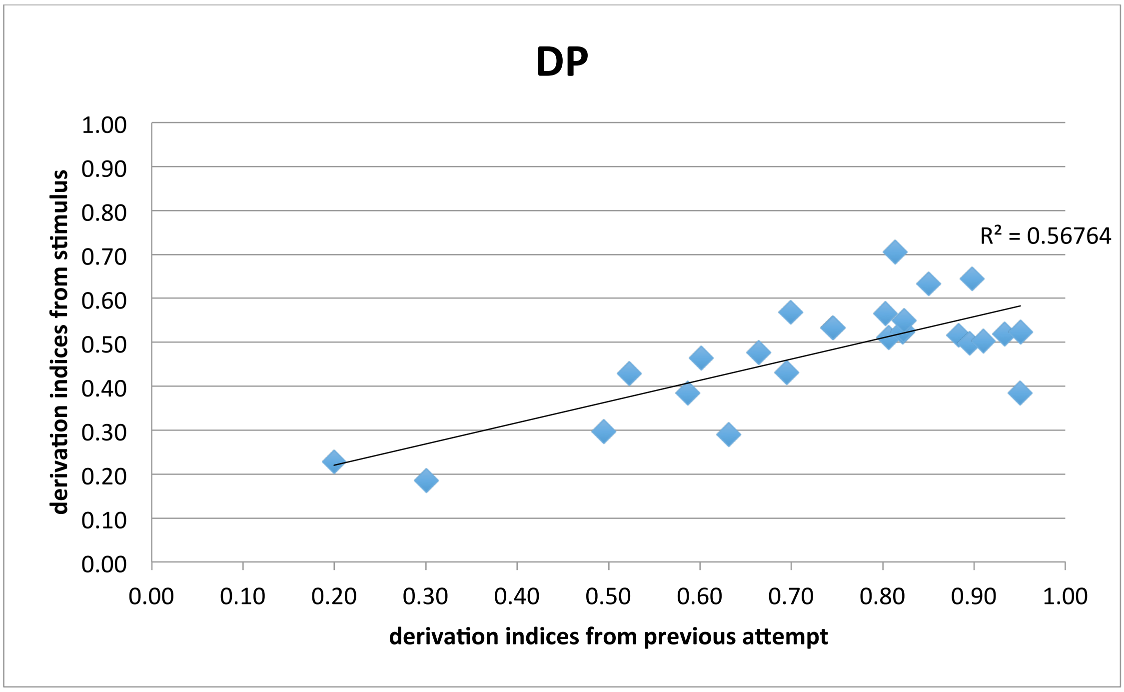


Fig. 5.34 DP's correlation between both sets of results.

GN recalled the external stimulus better than his previous responses on most occasions (Figure 5.35). The chart shows fluctuating results before the efficacy of different types of recall converge in the final session.

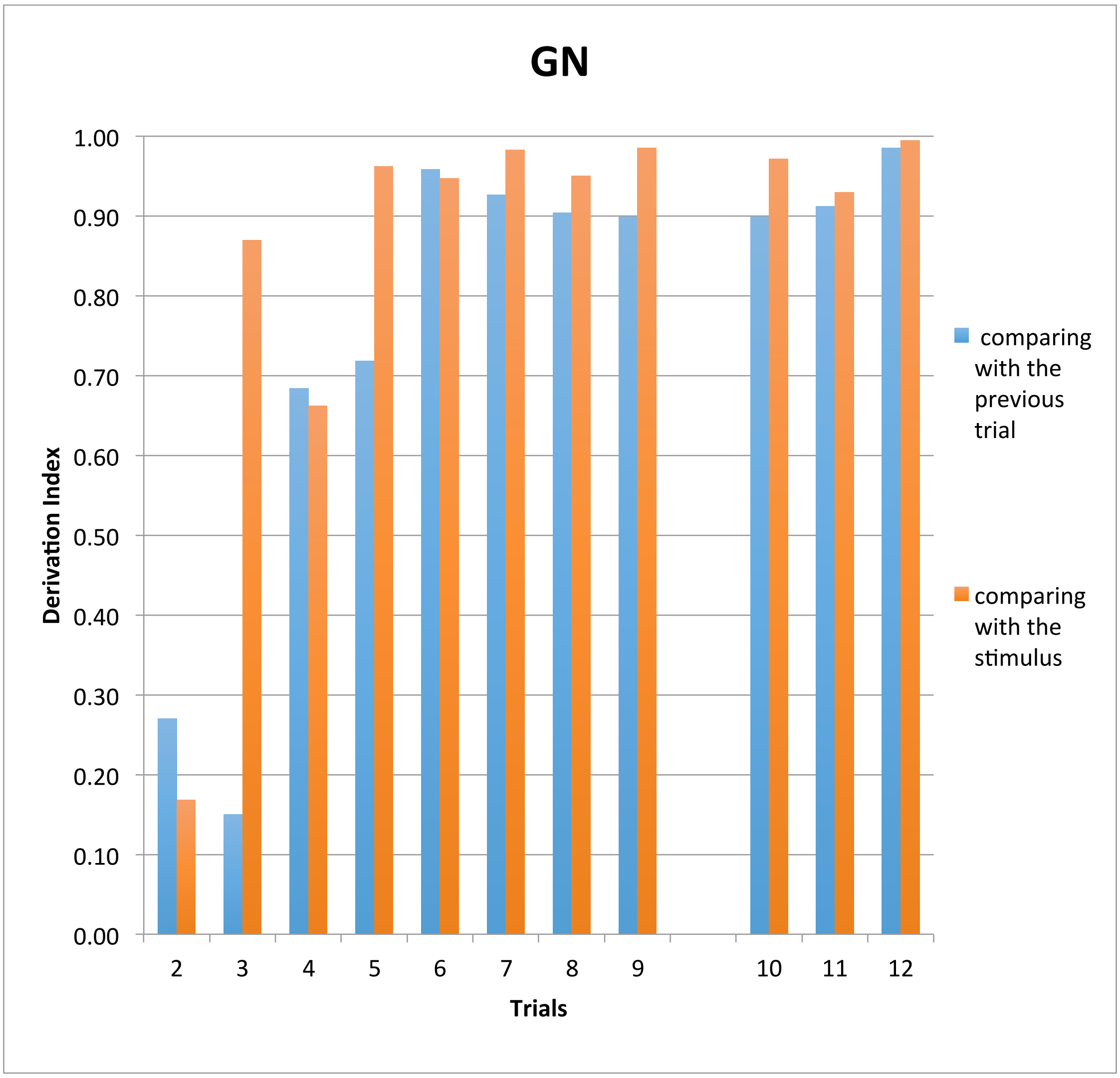


Fig. 5.35 GN's results for over all trials, comparing his responses with both the stimulus and the previous trial.

LP's results (see Figure 5.36) suggest a complex relationship between his memory of his previous responses and that of the stimulus. LP recalled the previous session compared to the stimulus better in trials two, four and six. Conversely he recalled the stimulus more accurately in the third, seventh and eighth trials.

When compared to his previous responses, LP maintained a consistent performance level from the second session onwards, which improved as the trials progressed. When compared to the stimulus, however, the trajectory of his performance showed considerable variations. Once he had learned the story (around the seventh session) the two memories (of the stimulus and the previous trial) began to converge, as we would expect.

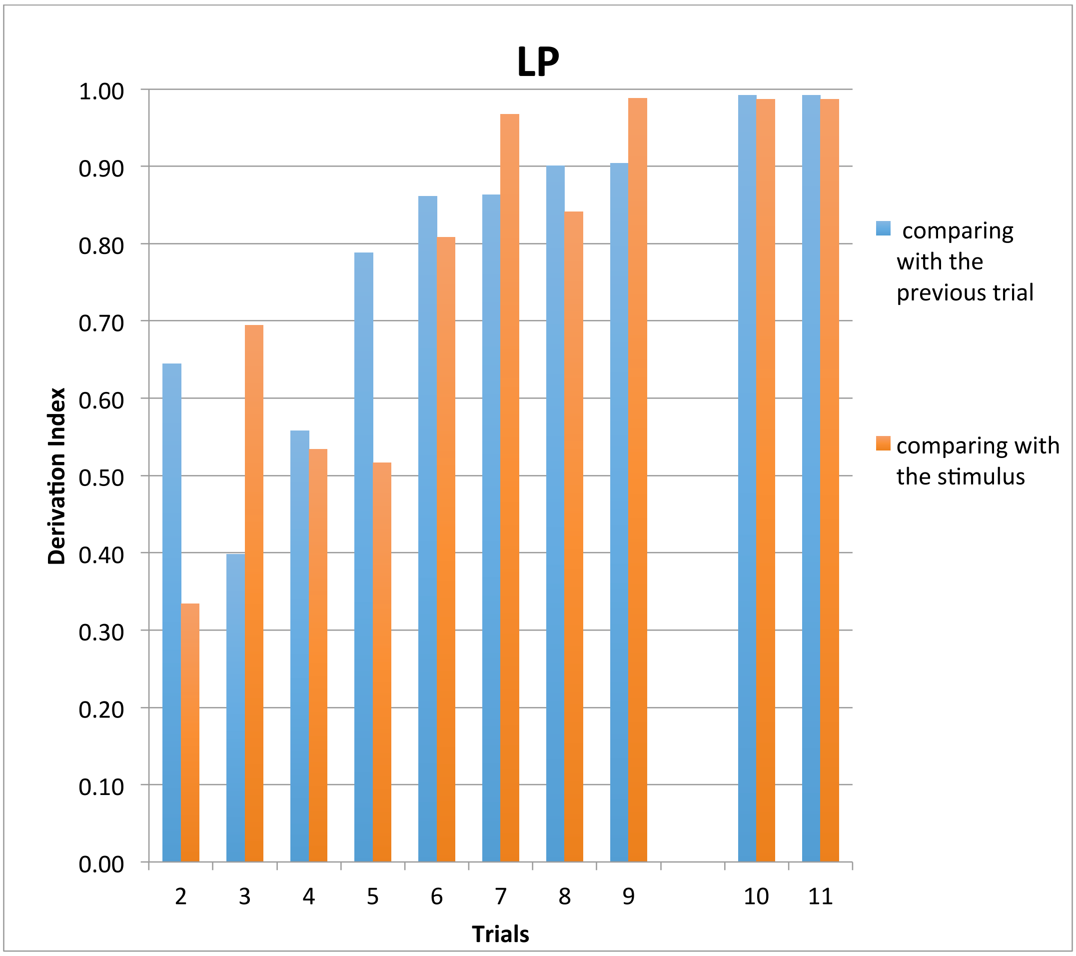


Fig. 5.36 LP's results for over all trials, comparing his responses with both the stimulus and the previous trial.

AN demonstrated that his memory for his previous responses was better than for the stimulus (see Figure 5.37). He maintained high scores throughout the trials, but with considerable discrepancies between scores in relation to the previous responses and the stimulus.

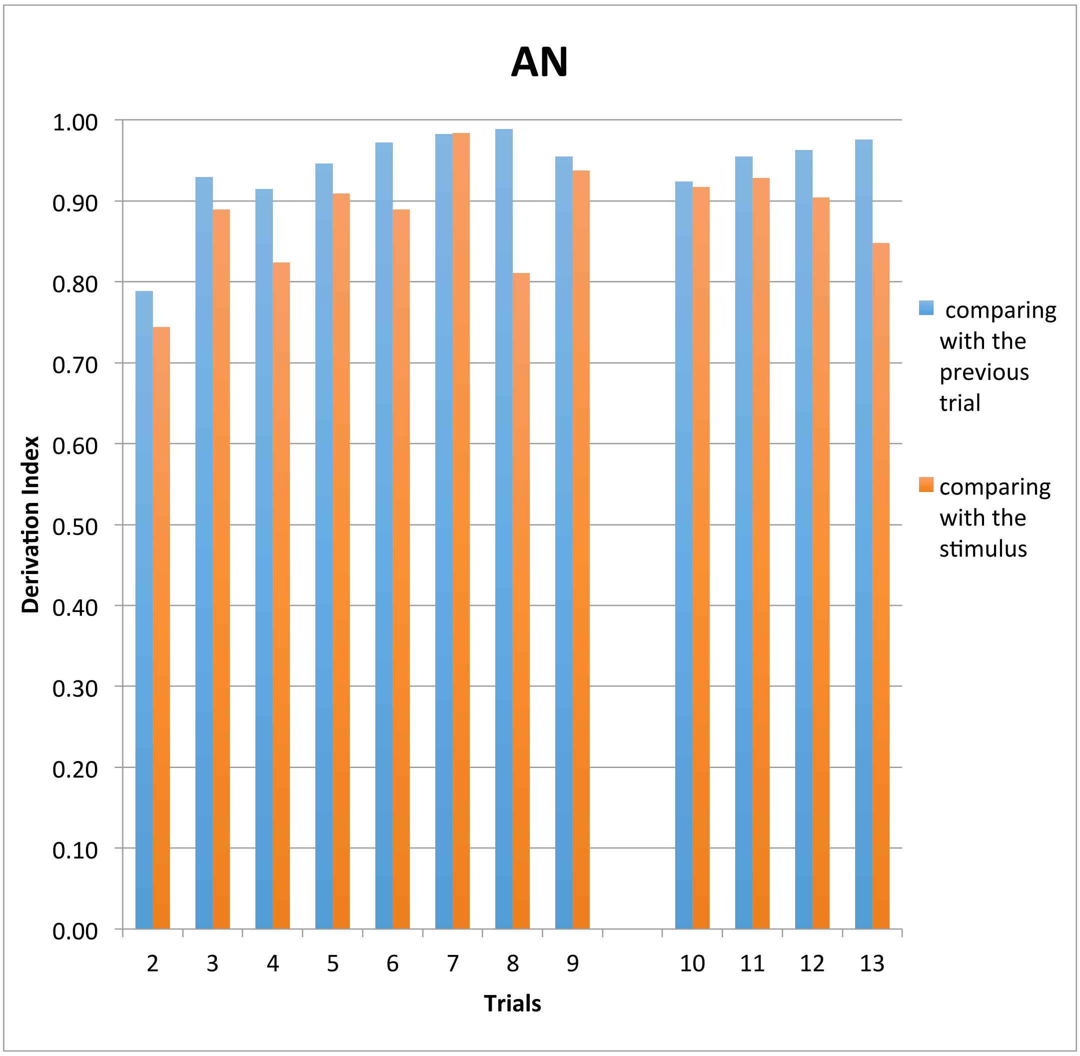


Fig. 5.37 AN's results for over all trials, comparing his responses with both the stimulus and the previous trial.

To summarise, DP and AN were better at remembering their previous responses than the stimulus itself, displaying a preference for their internal memory as opposed to the stimulus – in Piagetian terms, demonstrating a weakness for accommodating their (incorrect) schemata pertaining to subsequent hearings (of correct versions). DP's performance fluctuated considerably, whereas AN's performance was very linear, indicating that DP's learning process was intermittent compared to AN, who constantly improved as the sessions progressed. GN was the only participant who achieved higher scores in comparison to the stimulus than to his previous response, demonstrating his ability to assimilate the stimulus. LP's scores showed elements of both assimilation and accommodation working together.

5.6 Conclusion

This study has explored how DP processed a verbal stimulus, and compared this with another savant and two 'neurotypical' musicians with AP. It was expected that the data would confirm previous findings (Järvinen-Pasley et al. 2007; Ockelford, 2007; Ockelford, 2013) that when savants hear speech they are more likely to process aspects of this musically, indicating a reduced domain-specificity in auditory processing (Järvinen-Pasley and Heaton, 2007). However this was not found. In terms of the proposed model, it would appear that the semantic simplicity of the task meant that the hypothesised 'music module' was not activated.

Two possible outcomes of DP's efforts to learn the story were predicted by the model shown in Figure 5.3. The first was that he would fail to grasp the majority of the semantic content of the story and that he would activate a process of musical memory for words. The second was that if DP were able to understand the majority of the story, his verbal processing would predominate (rather than his musical processing), and the task would predominantly reflect his capacity to learn and remember words.

To expand on Ockelford's models (2007; 2013; see Figures 5.1, 5.2, 5.3 above), the less savants understand of the semantic content of speech, the more likely they are to direct it to the musical executive to be processed, and since language learning and recall in musical savants is known to be low, this may well occur often in everyday situations. Since, as we have seen, DP's verbal IQ is 58, it was expected that in the verbal memory task, the sounds of the words (sonance) would be recalled better than their meaning. However, it seems that the design of the task underestimated his verbal abilities, and in fact he was able to understand the story perfectly well. This is shown by his substitution of some words for others with similar meanings, and supports the hypothesis that DP can process speech that he finds easy to understand using the phonological loop. It is further hypothesised that, should the story have been semantically more complex, DP would have processed some or all of it using his musical executive, resulting in more accurate recall of the sounding quality of the speech (but with little understanding of its meaning). Further research could use semantic material of greater complexity to test the second part of the model.

In the meantime, several informal examples lend further support to the theory of the musical processing of complex verbal materials. Firstly, DP tends to resort to echolalia when he does not understand speech. For example, if a stranger were to ask him a question which he could not comprehend ('Why do you like music?') he would respond by repeating the question, suggesting that his focus is somewhat or entirely on the sounding quality of the words rather than their meaning, and, in terms of the model, that he is processing them using the musical executive and the STM music bundle, rather than exclusively the phonological loop. That is, echolalia provides an example of the musical processing of linguistic stimuli (Ockelford, 2013). On one occasion, DP was reported to have learnt by rote (with apparently little effort) the words of a Slovenian folk song (an entirely foreign language to him), demonstrating an ability to process speech using only the musical processing network, as the words did not hold any semantic meaning for him.

It seems that the other participants used different learning styles and strategies. For example, DP's scores improved (although exhibiting some fluctuation) during the first dozen or so sessions, reaching a peak at the 16th session and then (again with some fluctuation) decreased. However, the other participants displayed a more consistent, gradual improvement.

AN obtained the highest score overall, followed by GN, then LP with DP, by some margin, achieving the lowest level of recall. With regard to the variables analysed, it seemed that 'sequence' was partially independent from the others, as all the participants recalled semantics, syntax and sonance in more or less equal measure, but scored lower for sequence. It appeared that there were systematic problems across all subjects regarding the encoding of sequence. In particular, DP was entirely unable to grasp the structure of the story; this provides an interesting insight into his understanding and use of language.

With regard to the story's segments, collectively the participants achieved their highest scores in the first and the last segments. This effect was even more exaggerated in the case of DP.

All the participants exhibited higher results for working memory (WM) than long-term memory (LTM). DP showed difficulties in the consolidation of both LTM and WM, as he was not able to recall the middle segments of the story (in the correct place), despite having a good general understanding of the story.

Each of the four subjects demonstrated a different profile of recall, and different systematic and random errors were found across participants' responses. DP and AN most commonly added connecting words. DP added some words that were related to the stimulus, but most of them were distinct from it. All of AN's additions were present elsewhere in the stimulus. GN and LP added mainly adjectives and nouns rather than connecting words, but while LP used words that were present elsewhere in the story, GN added many words that were entirely different from the stimulus. This could suggest that LP was more focused on the task than GN. The savants were the only participants to include words beyond the content of the story (GN did this more than DP), although both stopped doing this after the first few sessions. In contrast, the 'neurotypical' participants did not make these types of errors; this could suggest that they were more focused on the task. DP had the highest number of omissions followed by LP, GN and AN. With regard to additions, GN had the highest number followed by LP, DP and AN.

At the end of their sessions GN, LP and AN had (more or less) learned the story (this was one of the reasons why the data gathering sessions were concluded earlier than for DP). Conversely, although he completed 27 sessions, DP did not really learn the story convincingly. DP seemed to extract ideas from his long-term verbal memory and attempt to combine them with the stimulus; sometimes he remembered parts of the story in a fragmented manner and endeavoured to 'glue' them together with non-stimulus materials. This gives us an indication what was going on in his mind. The task was too difficult for him, but he did his best to make sense of it.

Participants' responses were also compared to their recall in the previous session as well as to the stimulus. The two appeared to be fused in DP's mind; AN's responses showed a similar pattern to DP, however his performance was more accurate, suggesting that DP's learning process was more irregular than AN, who was continuously improving as the sessions progressed. The only participant who achieved higher scores in relation to the stimulus rather than the previous session was GN, suggesting that his long-term memory was less affected by new input. LP showed no differences in results for the two types of analysis. Overall, the participants who found the task more difficult (such as DP) relied more on the recall of their previous attempt.

To conclude, the present study showed differences in the learning styles and strategies of all the participants. The idiosyncrasies discussed above suggest that far more research would be necessary with larger groups of both savants and 'neurotypical' subjects, in order to draw more general conclusions.

CHAPTER 6: GENERAL DISCUSSION

6.1 Introduction

The aim of this thesis was to explore the perception, learning and memory of a prodigious musical savant, DP, through comparison with other savants and 'neurotypical' musicians with absolute pitch. While some research has previously been undertaken with musical savants (e.g. Miller, 1989; Heaton et al. 2008; Pring, 2005b; Ockelford, 2008), there are still gaps in our knowledge (e.g. regarding their perception, cognition, learning and memory). After critically reviewing the literature, my research interest was to explore aspects of savant musical behaviours more deeply. The main case study in this research is DP; his abilities are considered both in their own right, and in comparison with those of other savants and 'neurotypical' musicians with AP. The research questions were as follows:

Research question 1:

Perception
Given that musical savants have AP and an ability to disaggregate chords:

1) To what extent and in what ways are the chordal disaggregation abilities and strategies displayed by DP typical of other savants and 'neurotypical' musicians with AP? Specifically:

    1a) What are savants' capacities for disaggregating chords (including simple and higher diatonic combinations of notes, chromatic composites, and clusters which have no tonal implications)?

    1b) What is the impact of chordal size, structure and complexity on savants' perception of them?

    1c) Is it possible to identify particular strategies that savants may use for disaggregating chords?

    1d) Do these strategies differ from those used by 'neurotypical' musicians with AP, and if so, in what ways?

Research question 2:

<u>*Learning and memory in music*</u>

Given that savants typically learn pieces intuitively, by listening and playing:

2) To what extent and in what ways is DP's capacity to learn music by ear affected by the mode of presentation? Specifically:

> 2a) What impact (if any) does the (enforced) strategy of breaking a memorisation task down into small chunks and doing 'a bit at a time' have on DP's learning and recall (compared with learning a piece 'all the way through')?

Research question 3:

<u>*Learning and memory in verbal material*</u>

In order to further clarify domain-specificity and the possible existence of a music module in working memory:

3) To what extent and in what ways is DP's capacity to learn and recall music domain-specific: in particular, how does it compare with his ability to learn and recall verbal material? Specifically:

> 3a) How do DP's verbal memorisation abilities compare with those of another savant and 'neurotypical' musicians with AP?

6.2 Discussion of research question 1

The foundation for the research reported in Chapter 3 was the work conducted by Ockelford (2008), in which he described the chordal disaggregation abilities of DP, another savant and one comparison subject, a 'neurotypical' musician, and considered the possible strategies that each was employing. The limitations of his study were the size of the sample used, the number of variables considered in analysis of the chords and the limited accounts of the strategies applied by the participants. Hence, it was of interest to further explore this issue systematically and more extensively, with a larger sample size.

Within the current study, a chordal disaggregation experiment was performed employing the same chords used by Ockelford (2008). Responses were analysed in terms of the following variables: size of chord, position of note in chord (top, inner or bottom), style (tonal or 'non-tonal') and complexity. This enabled the strategies used by the participants to be identified and their significance discussed. Twenty-three subjects participated: a group of savants (*N* = 6) and 'neurotypical' musicians with AP (*N* = 17). DP was the most successful; and overall the savants performed better than non-savants across all chord sizes. There was an overlap between the highest scores amongst the non-savants and the lowest scores of the savant group suggesting important commonalities in terms of strategies applied. However, there was much variation within groups.

With regard to chord complexity, savants outperformed non-savant comparison participants across all four levels of complexity, although, as the chords became more complex the accuracy of the scores decreased in all participants. DP and other savants were better at disaggregating chords that conformed to familiar tonal patterns rather than clusters, demonstrating that these savants, at least, were able to comprehend global musical structure. This suggests a similarity in the way that savants and non-savants perceive chords, implying that both groups are affected by structural complexity. Absolute pitch, which was a prerequisite to participate in the study, does not operate in isolation: chordal structure (entailing relative pitch judgements) has an impact too.

Across both tonal and non-tonal chords, the savants consistently outperformed the non-savants, but both groups are affected by tonality (or a lack of it). That is, the familiarity that both groups have with Western pitch structures means that participants were better able to disaggregate tonal than non-tonal chords. Again, this suggests that there are similarities in the way that savants and non-savants process chords, although non-savants would have studied the harmony in a conceptual sense.

Analysis of the top, inner and bottom notes of the chords illustrated that savants and the least successful non-savants achieved ‘opposite’ scores. This implies that they processed the notes differently (according to their relative position) and applied different strategies. Savants and the highest scoring non-savant comparison participants achieved better results for the accuracy of the bottom note, which usually functioned as the root (bass) of the chordal structure. This could indicate that the savants and some of the non-savants were adopting a similar listening strategy that is more interrogative of harmonic structure. However, the remaining non-savants were more consistently accurate with the top notes rather than the bottom notes, for which they proportionately made more errors. Clearly, this could have implications for the way that musicians are usually educated.

Previous research into the disaggregation of chords (Charness, Clifton and MacDonald, 1988; Miller, 1989) employed fewer numbers of stimuli that comprised only four simultaneous pitches, and involved fewer participants. Furthermore, only simple analyses were undertaken that took into consideration just the number of pitches that were correct. Hence, only a limited investigation of the *strategies* that the subjects used to perform the task was undertaken.

The study by Charness et al. (1988) explored the musical abilities of the savant JL, who had been born prematurely and had retinopathy of prematurity (at the time known as ‘retrolental fibroplasia’) – the same condition as DP. Like DP, he was reported to be blind, to have learning difficulties and limited verbal language, including echolalia. Unlike DP, however, he had episodes of epilepsy and moderate right hemiplegia.

In their first experiment, Charness et al. (1988) used 30 ‘conventional’ and 30 ‘unconventional’ 4-note chords. ‘Unconventional’ chords were classed as triads, one note of which was raised by a major seventh or minor ninth. Hence the classification bore some similarity to the categories used here of ‘tonal’ and ‘atonal’ (although the atonal chords used in the current research had more variety). JL's responses to the conventional and unconventional chords did not differ significantly. The results achieved by JL (93%) are comparable to three of the savants (VX, LH and NS – with unweighted scores of 94%, 93% and 91% respectively; see Table 3.12) on 4-note chords, whose achievement was in the mid-range of the savants whose results are reported in this thesis. An important similarity is that it appears that JL tended to work 'from the bottom up', often omitting the top note when it had the same tonal function as the bottom one, a strategy used by the group of savants in the current research. (It should be noted, however, that JL was only able to play with this left hand.) Moreover, Charness et al. (1988) did not weight their results according the probability of JL playing combinations of notes by chance, which in his case may have had a greater effect, since the number of combinations he was able to play was more limited (having only one hand available). This may have had the effect of suppressing JL's results somewhat.

Miller (1989) also used 4-note chords (24 of them, taken from those used by Charness et al., 1988) – a mixture of the 'conventional' and 'unconventional'. In his sample he included an 'AP group' formed of three savants – a child and two adults (Eddie, DW and CN); a further adult who had autism spectrum disorder (ASD)(but was high functioning) (MB), one who was 'neurotypical' (BA) and a child who was blind (KL). The results were as follows. Eddie, DW and CN scored higher for conventional chords (each achieved 98%) than for the unconventional (M = 93%), which ranged from 88% to 95%. MB scored the highest of the group for conventional chords (100%) and among the lowest for unconventional (90%). BA and KL each scored the same for conventional and unconventional chords, with the former scoring 95% and the latter 83%.

Results from my research are very much in line with Miller's: the savants' raw scores for 4-note chords had a mean of 94%, within a range of 86% to 100% compared to a mean of 95% within a range of 88% to 98% in Miller's sample. The participants' scores included in my comparison group range between 13% and 99%, with an average of 57%. This implies that Miller's 'neurotypical' participant was highly skilled, with a score (95%) only bettered by one of my 'neurotypical' participants with AP. The participant with ASD scored an average of 95%, and the blind child scored on average 83%. It is interesting to note that these two participants achieved results that are similar to those achieved by my group of savants, all of them being on the autism spectrum and visually impaired. Hence, in summary, the results reported here are consistent with, and extend, previous research.

6.3 Discussion of research question 2

Miller (1989), and Young and Nettelbeck (1995) researched how savants learn and memorise musical material. However their work focused on short-term memory (unlike the research reported here) and the studies used different techniques to the ones used here to analyse the material. Studies on long-term musical memory with professional pianists were undertaken by Ginsborg (2002), Chaffin (2007) and Ginsborg and Chaffin (2011). Of particular interest in the current context is the study by Imreh and Chaffin (1997), in which a concert pianist recorded her practice as she learnt the last movement of the *Italian Concerto* by Bach. Here, however, the emphasis was on the private rehearsal needed to acquire the technical expertise needed to play the piece, although considerations of memory also played a part – in particular the issue of distinguishing between sections that were similar (though had important differences). This was done on a *conceptual* level (something that was not open to DP), and, as we saw in Chapter 4, these larger structural issues tended to elude him, and he would reverse sections B1 and B2.

With regard to long-term music memory in savants, Ockelford and Pring (2005) conducted the first scientific study in this field (*Chromatic Blues*). The current work builds on this, by using an original protocol ('a bit at a time'). In both *Chromatic Blues* and the current study, the use of zygonic theory (Ockelford, 2005) allows for measures to be taken systematically. These gauge consistently and coherently the degree of imitation between the stimulus and the response, taking into consideration the variables pitch and rhythm, and the top, inner and bottom parts of the texture.

As noted above, the research reported in Chapter 4 extends Ockelford's research (2012), in which DP attempted to learn and recall a specially-designed piece of music called *Chromatic Blues* over a period of four years by listening to the entire piece and trying to play it back as a whole. In the current study DP was asked to complete a musical memory task, to the best of his ability, which tested another method of learning and recall that was thought to reflect a more typical approach to learning – bar by bar. The experiment tested how DP responds to the 'neurotypical' learning method of breaking things up into chunks. This research can be seen in the broader context of the 'REMUS' Project (Researching Exceptional MUsical Skill, described in section 4.2) and complements Ockelford's 2005 proposal for a series of studies that explore the ways in which DP characteristically learns music. Therefore, the current investigation adds the 'bit at a time' method of learning to the continued exploration of DP's musical processing.

Previous research on memorisation (Rubin-Rabson, 1940) found that the process of breaking down large tasks into small chunks usually facilitates learning. However, for people on the autism spectrum, there is a debate in the literature concerning local versus global learning and information processing. The Weak Central Coherence (WCC) theory (Frith, 1989) suggests that autistic people demonstrate a detail-focused processing style and a bias against global processing; however, more recent studies have challenged this theory. Happé and Frith (2010) describe mixed findings regarding weak global processing in people on the autistic spectrum.

To further explore the memory processes involved in learning for those on the autism spectrum, specifically in relation a musical savant, this research presented a new stimulus, *Classical Turn,* which was structurally equivalent to *Chromatic Blues* (to enable comparisons to be drawn). The *Classical Turn* experiment involved two conditions of learning and recall. In the first, ‘a bit at a time’ (BT), DP was asked to replicate each bar immediately after hearing it. In the second condition, the ‘whole piece’ (WP), DP listened to the entire stimulus at the end of each session. He was not asked to play the stimulus again until the beginning of the session that followed.

The results of this research suggest that in terms of DP’s musical learning and memory abilities, his capacity to learn music by ear is affected by the mode of presentation. In fact, when comparing the overall results between WP and BT, in the WP condition, DP achieved poor results, with an average derivation index (DI) of Z = 0.21. This low score is mainly due to the large number of omissions he made. Regarding the BT condition, from the first trial DP replicated the bars heard with an average DI of Z = 0.62 and the improvement between sessions was minimal and erratic. A more faithful reproduction of what was heard was expected here, since the stimuli were brief – yet he did not even achieve average DIs as high as those in the *Chromatic Blues* experiment, which, as we have seen, involved him learning an entire piece at once (*cf. Chromatic Blues*; Ockelford, 2012).

Indeed, it is striking how poorly DP performs in general compared to his level of achievement with *Chromatic Blues* (Ockelford, 2012). There appear to be two main reasons for DP’s relatively weak performance. First, in both the BT and WP conditions, he persistently added extra notes to the ‘turn’ in the original. Second, in the WP condition he invariably omitted a number of bars: the most he ever played was 12 out of 19. Furthermore, in all the odd-numbered bars within the piece he added a quintuplet that made perfect musical sense, but that was not present in the stimulus, meaning these bars contained errors that significantly affected the DIs.

When comparing the *Classical Turn* experiment to the chordal experiment similarities have been found in the results, particularly in terms of accuracy in the top, inner and bottom parts. In the former the bottom note was more accurate followed by the inner and the top, in the latter the bottom note was more accurate followed by the inner and the top. To summarise, DP recalls the bottom notes with more precision in both experiments.

We now compare the overall results obtained for *Classical Turn* and the previous experiment by Ockelford (2012), *Chromatic Blues*. As we noted above, *Classical Turn* was designed to have the same structure and to be a similar length to *Chromatic Blues*. In every session, DP was far more successful in recalling *Chromatic Blues* than *Classical Turn.* Figure 6.1 shows the results achieved by DP in *Classical Turn* for the whole piece condition compared with *Chromatic Blues*.

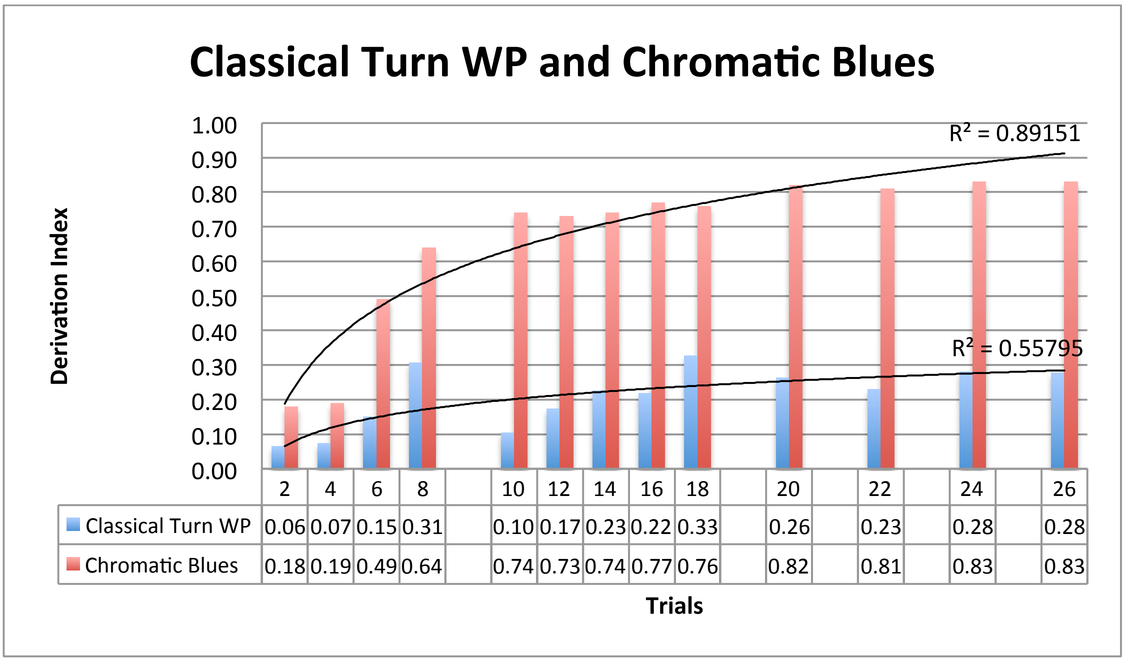


Fig. 6.1 *Classical Turn* whole piece and *Chromatic Blues* results.

There are two striking features of DP's attempts to recall *Chromatic Blues*: the accuracy he achieves (with a final DI of over 0.80, despite a two year break) and the fact that he often confuses the sequential order of sections B1 and B2. This is in line with WCC theory (Happé, 1999; Brunsdon and Happé, 2013), with its suggestion of attention to detail at the expense of the overall picture. In *Classical Turn*, this problem is exacerbated, since half DP's exposure to the stimulus was fragmented. It could well be that this was a major contributory factor in his inability to grasp the overall structure of *Classical Turn*, which DP never mastered, omitting a great deal of material even in the later stages of the experiment. It seems that this omission was a result of his having only a weak sense of the structure of the piece as a whole. Hence he did not have the structural cues that would have enabled him to 'slot in' his detailed memories at the appropriate junctures.

It is interesting to note that this learning strategy of breaking things down, which might be thought of as conventional and effective for some, did not help DP at all. In fact it may have hindered his ability to recall. In particular, although he was able to correctly replicate individual bars it was apparently his inability to hear the overall structure that may have caused problems.

It is possible to draw further detailed comparisons with *Chromatic Blues*, as the same analytical protocol was followed. With regard to pitch and rhythm, in *Chromatic Blues* the grand averages are identical. In *Classical Turn* DP scores Z = 0.23 for pitch and Z = 0.19 for rhythm. This is probably due to the systematic mistakes he made that mostly involved rhythm. Concerning the scores for top, middle and bottom parts, in *Chromatic Blues* similar scores are achieved for the top and bottom parts, while the inner parts are consistently weaker. A similar pattern is found in *Classical Turn,* where DP achieved the following DIs: top (Z = 0.62) inner (Z = 0.60) and bottom (Z = 0.66). This shows that, DP's aural analysis of the texture was unaffected by the mode of presentation.

Clearly, a limitation of the study is that the two pieces were necessarily different (although both used styles that DP was comfortable, and a comparable level of harmonic complexity). Nonetheless, one cannot discount the fact that the differences between the pieces may have contributed to the differences in the DI scores between them.

6.4 Discussion of research question 3

As we noted in Chapter 5, the work of Järvinen-Pasley et al. (2007), which indicates that the melodic component of speech is processed better by people with autism than by controls (demonstrating a reduced domain specificity in auditory processing for those with autism), led to the hypothesis the DP would process and remember the sounding quality of a story (sonance) with greater accuracy than the meaning (semantics). This also accords with Ockelford's (2013) theory of 'Exceptional Cognitive Environments', that suggests that some children on the ASD may process language as though it were music. This hypothesis was placed in the context of Baddley's model of working memory, which posits the existence of a 'phonological loop', and the question was raised as to whether there may be an additional 'music module', perhaps in the case of some people on the autism spectrum, or even more universally. As we discussed above, this would tie in with Patel's (2012) theory of music and language processing in the brain, in which music and language are held to be stored independently, though with some sharing of neural processing networks.

To ascertain how well DP and the other participants recall verbal information compared to musical material a story was created that was analogous to the structure of *Chromatic Blues* and *Classical Turn* (*cf.* Chapter 4). The protocol for the experiment was the same as for *Chromatic Blues* (that is, listening to the whole piece through trying to recall it and then listening again), and a similar timetable was followed for comparison purposes.

For the purposes of comparison, three other participants learnt the story too: another savant (GN) and of two 'neurotypical' musicians with AP, who were also involved in the chord disaggregation experiment (see Chapter 3). The content of the stories focussed on the previous personal experiences of the savant participants, in order to facilitate their memory for the stimulus.

The hypothesis that DP would recall sonance better than semantics (*cf.* Järvinen-Pasley and Heaton, 2007) was not supported. In terms of the proposed model, it would appear that the semantic simplicity of the task meant that the hypothesised 'music module' was not activated.

In a different study, Reece (2014) found that children with ASD who were in the early stages of language development (at the two word level or below) found music helpful in learning and recalling words in songs (presumably since they were processing the words as another 'asemantic' stream of musical sound), whereas those who were more advanced linguistically found the music a distraction – in other words, there was an attentional conflict.

This may shed some light on the results of DP's verbal memory test compared with his learning and recall of *Chromatic Blues*, and what it implies for our understanding of the potential modularity of his auditory processing. Figure 6.2 shows the DIs of all the sessions (27 trials) over a four-year period for both the verbal test and *Chromatic Blues*. The x-axis displays the trials conducted with DP, and the *y*-axis shows the derivation indices achieved. The blue bars display the scores obtained in the verbal memory trials, and the red bars show the score achieved in the trials of the musical memory experiment. The graph shows that DP achieved higher scores in the musical memory trials than the in the verbal memory experiment. His musical memory DIs (red bars) did not progress in regular increments: initially his performance dropped from the first through to the third trial, however by the fourth trial there was a noticeable improvement in his performance until the ninth, with a slight decrease on the eighth trial. From the eighth he maintained almost the same level of performance with slight variations until the eighteenth. From the twentieth to the twenty-seventh trials the performance improved with some variation until the end of the sessions. It seems that for the musical test, after showing improvement, DP's DIs 'flatten out' with no further improvement. The verbal memory performance (shown in the blue bars), demonstrates that from the first to the fifth sessions the scores were higher than the musical memory performance. However from the sixth there was a sharp decrease and wider variations between performances until the end of the experiment.

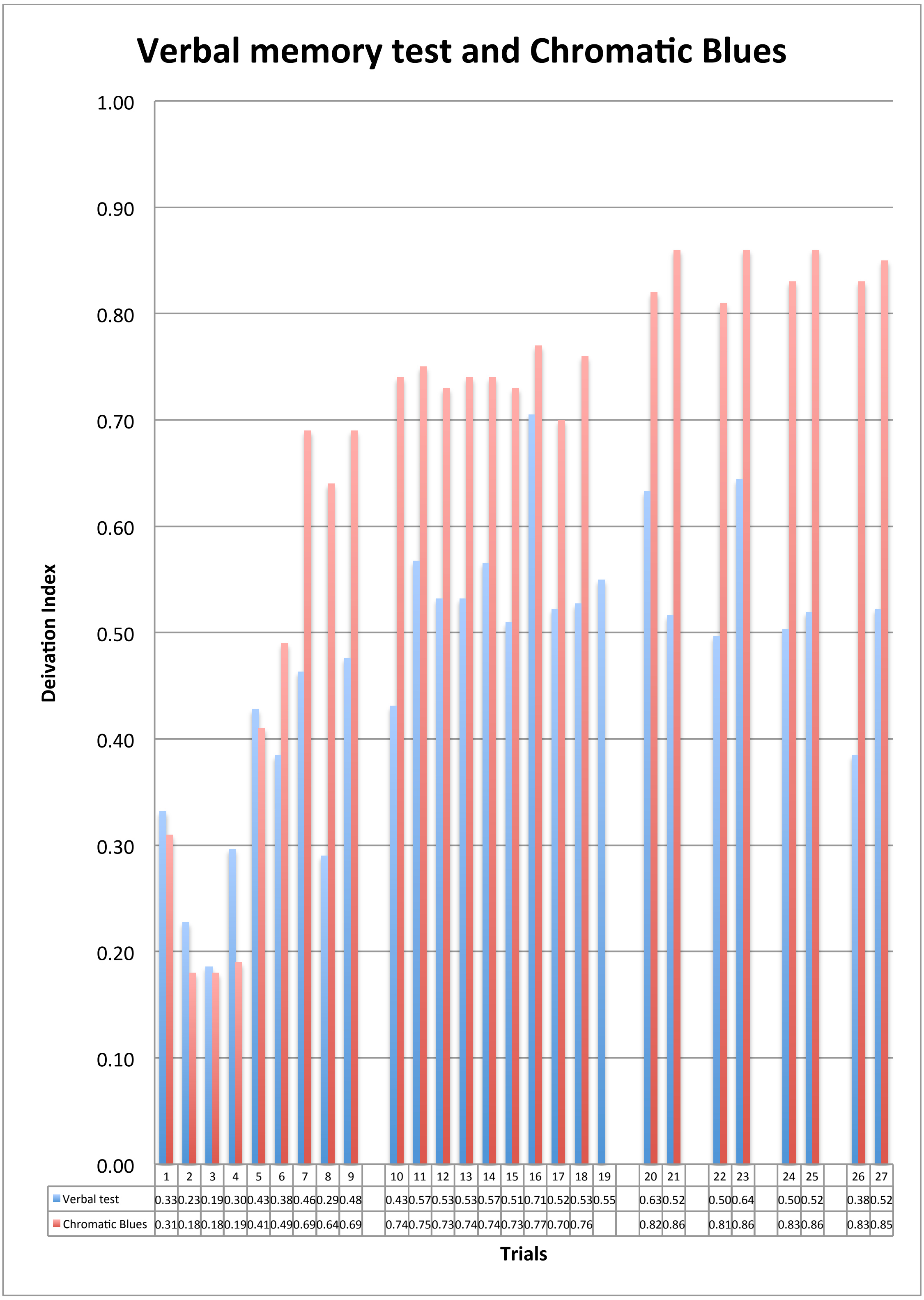


Fig. 6.2 Verbal memory and musical memory test (*Chromatic Blues*).

There is a striking similarity between DP's DIs in the first five trials (see Figure 6.3) – with an initial score for verbal memory test of Z = 0.33 and for musical memory $Z = 0.31$ and then a drop to $Z = 0.23$ for verbal memory and to $Z = 0.18$ for musical memory. The correlation between the two patterns of DIs is significant: $R = 0.76$, $p = 0.02$.

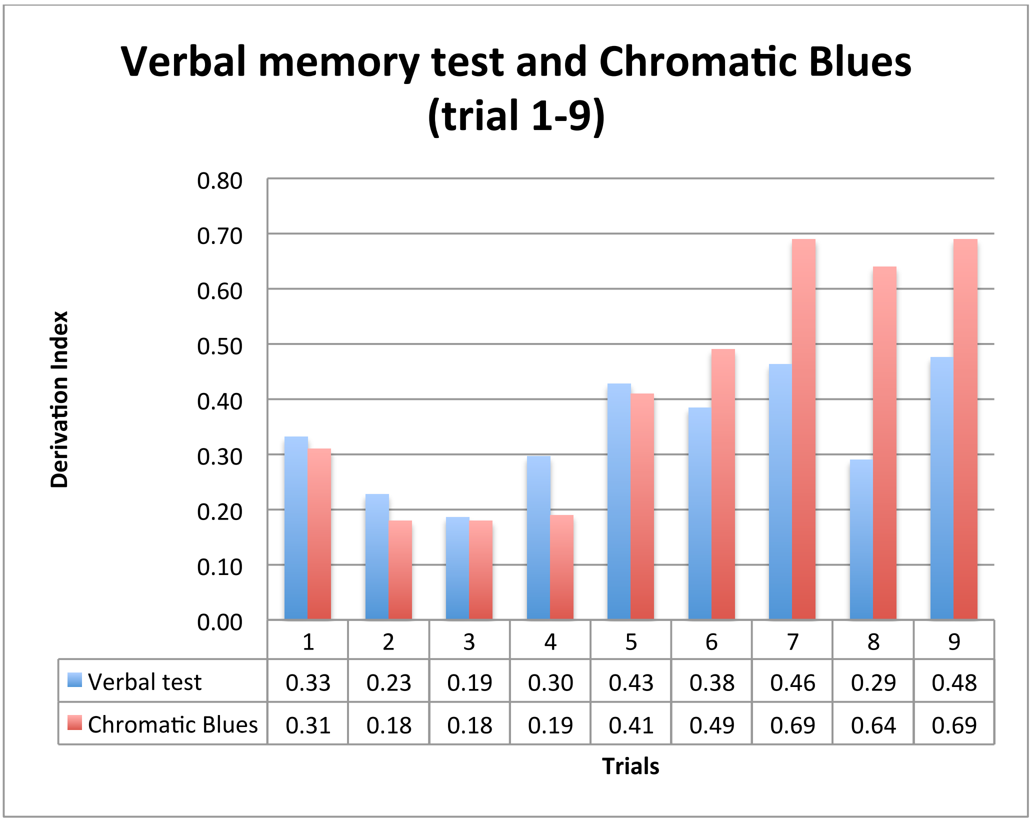


Fig. 6.3 Verbal memory and musical memory test (*Chromatic Blues*) (trials 1-9).

Then, in the second phase, there is a tendency to a slower improvement for the verbal memory test and no improvement at all for the musical memory test (see Figure 6.4).

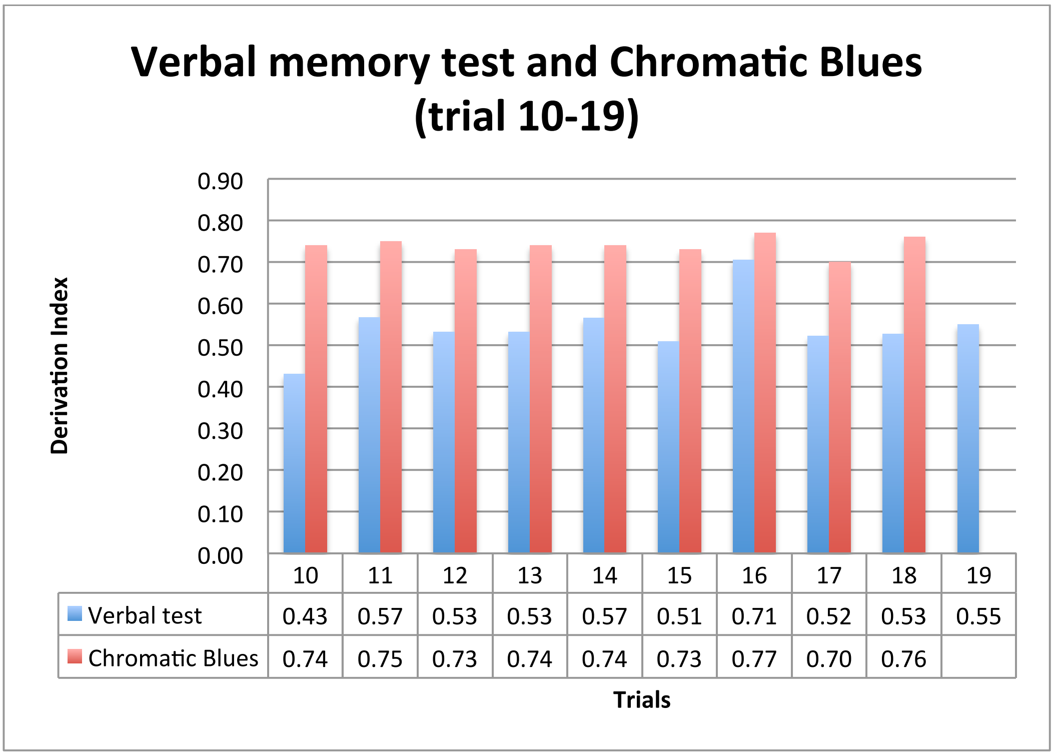


Fig. 6.4 Verbal memory and musical memory test (*Chromatic Blues*) (trials 10-19).

Then in the third phase, with long periods between trials – the music slightly improves but the DIs for language show a decline – see Figure 6.5.

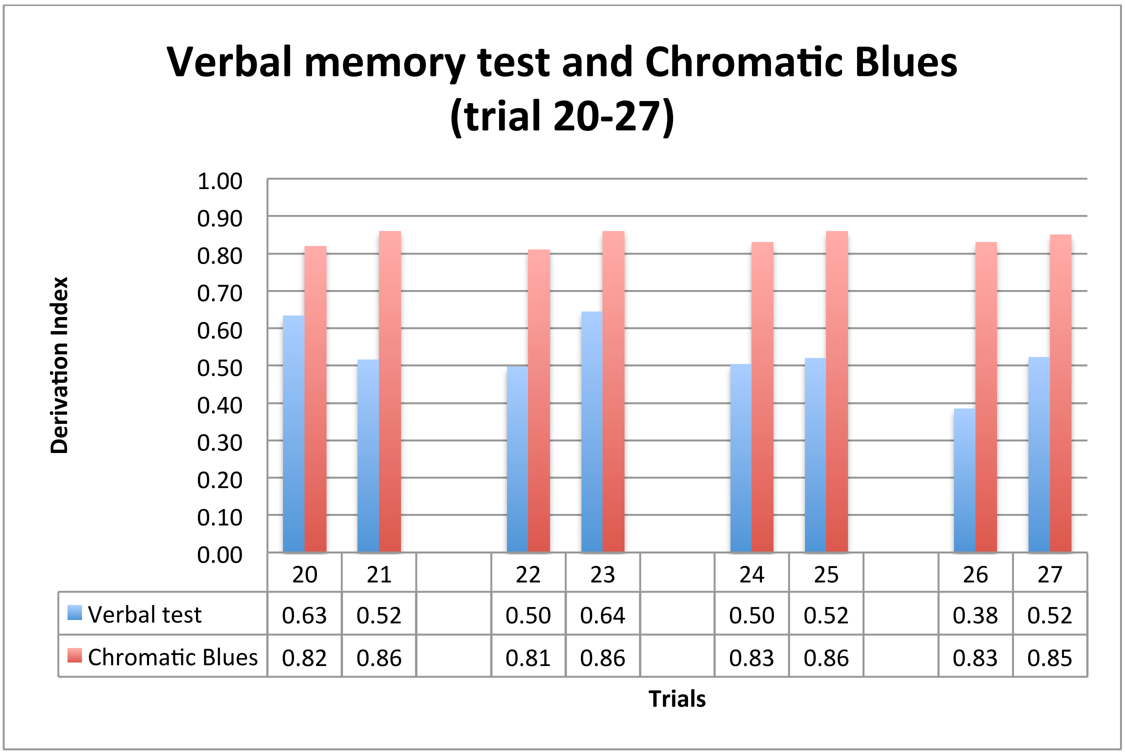


Fig. 6.5 Verbal memory and musical memory test (*Chromatic Blues*) (trials 20-27).

When comparing the two tests, the scores may be interpreted as indicating a tendency for DP to hear musical structure rather than linguistic structure. One may surmise that people with cognitive processing similar to DP have a music module for working memory, but this does not necessarily mean that 'neurotypical' musicians possess this 'music module' as well. In addition, a common feature between the two experiments is that DP remembers his errors in the verbal experiment and also systematically repeats his errors in *Chromatic Blues*. In this way, his learning (or failure to learn) was similar in both modalities. Finally, note that it appears DP failed to grasp most of the structure of the story, just as he failed to grasp a key element in the structure *Chromatic Blues*. And in seeking to recall the story, DP drew on a variety of ideas from past experiences, in a similar way to his introduction of familiar musical material into his attempts to reproduce *Chromatic Blues*. Subsequently, he attempted to combine all of them; sometimes he remembered things in a fragmented manner and endeavoured to merge them.

6.5 Chapter summary

The results achieved in this thesis provide new insights in the field of perceptual learning and memory in musical savants, drawing on in-depth analyses of both musical elements and the processes of learning and recall. Within the chordal disaggregation experiment various aspects of the chords were examined such as size, complexity, tonal content, and note position (top, inner or bottom). The learning strategies (‘a bit at a time’ and ‘whole piece’) used by participants were also explored, as well as the semantics, syntax, sonance and sequence in the verbal experiment. Analysis of their behaviour and performances provide us with a picture of their cognitive abilities in terms of verbal and musical content. The current study complements and extends the theory that musical savants possess a different cognitive style (Happè, 1999), which involves their way of thinking about, listening to and approaching the world around them. This is the focus on the next chapter.

CHAPTER 7: CONCLUSION

7.1 Contribution to knowledge, constraints and next steps

As we noted in the literature review, savants are individuals who evince a wide discrepancy between their disability and a marked ability (or abilities). The term 'savant' is widely used: Treffert (1989) provided a descriptive profile, defining savants as 'talented' or 'prodigious': in the latter, a much rarer condition, the ability is not only remarkable in contrast to the disabilities, but would be significant even if viewed in a 'neurotypical' person. In the former, a savant's skills are unusual only in contrast to their disability, but not necessarily with reference to a non-disabled population. More systematic evaluations by, for example, Heaton and Wallace (2004) and Pring (2005b), as noted in the literature review (*cf.* Chapter 2), have approached the topic of savantism by looking at the neuropsychological basis of autism, seeking to explain the phenomenon with theories such as weak central coherence (Frith, 1989). Ockelford (2000) contends that savants exist on a number of continua of different skills and areas of need. His position is that, while the population may be well-defined in archetypal cases, there will be people whose particular combination of abilities and disabilities mean that using the label 'savant' is problematic.

The research that has been set out in this thesis makes a contribution to this debate. Although the savants who participated in the research were, apparently, a homogeneous group (all with severe, congenital visual impairment, learning difficulties and an exceptional ability to play the piano by ear, which manifested itself early in life) there were important differences too in the manner in which musical (and in some cases verbal) stimuli were processed. Among the key similarities were an exceptional ability to disaggregate chords, which was informed by a common strategy (whereby simultaneous pitches were apparently processed from the lowest to the highest). Moreover, all the savants found tonal chords easier to disaggregate than non-tonal (indicating that all had internalised the rule-based nature of the Western tonal system), and in every case, their responses were affected by the size of the chords (four to nine notes), suggesting that similar auditory discrimination strategies were in play (although the absolute capacity to reproduce chords of different sizes varied). Chordal complexity (simple diatonic, higher diatonic, chromatic and note cluster chords) also had a similar affect on all the savants' results, although, again, in absolute terms their results differed. It could be that the differences in their chordal disaggregation capacities resulted either from different levels of cognitive processing capacity or varying levels of ability to play rapidly by ear, or both. Future research would be required to resolve this issue. A key finding here is that, although DP demonstrated similar approaches to those used by other savants and skilled musicians with AP, he scored much higher than all other participants in the chordal disaggregation experiment. From the foregoing discussion, it would appear that this greater success should not be attributed to different strategies but to more advanced skills within the strategies that he used.

Regarding the advanced 'neurotypical' musicians, it appears from the chordal disaggregation results that their perceptual processing (and their ability to reproduce what they hear rapidly on the keyboard) is, generally speaking, less refined than that of the savants. However, they have the advantage of being able to rely on a conceptual (metacognitive) strategies to help them when perception breaks down. Informal discussion following the test suggested that, in some cases at least, when they were perceptually challenged, they would rely on music-theoretical understanding to help them out – for example, conceptualising a chord as 'diminished with added notes'. Again, this is an area for further investigation in the future. For now, it appears that, despite this difference, music provides an interpersonal space in which savant and neurotypical musicians can meet.

Regarding DP's learning and memorising a musical piece, his relative difficulty in learning a piece 'a bit at a time' supports the notion of 'weak central coherence' – that people with autism tend to process detail and use this to build up gestalts, rather than perceiving larger structures as a whole and using these to position and understand particular items of detail. Yet it is this intense attention to detail – so-called 'enhanced perceptual functioning' – that may well have been the key to the development of his exceptional talent in the first place (as a very young child, Happé and Vital, 2009).

As far as the notion of 'modularity of mind' is concerned, in DP's case, the verbal memory experiment provided striking evidence of intelligence being encapsulated in a particular domain, with little or no transfer effect. However, this was not found in GN's results, which showed a greater equivalence in musical and verbal processing capacity (being lower than DP in the musical tests and higher in the verbal tests). Hence it may be that general and specific areas of intelligence function differently, even within the savant population. DP's capacity to process, store and remember language (in auditory form) is very weak compared with his achievements in music memory, suggesting that it is indeed distinct from his music-processing capacity. These data could suggest the possibility of there being a discreet 'music module' in working memory already hypothesised by Ockelford (2007b), although more evidence would be needed to generalise this theory to other musical savants.

In terms of practical application, the results of my research have implications for music education – particularly for those working with children on the autism spectrum with AP (estimated, as we have seen, to be at least 5% of that population). The 'bottom up' processing strategy of chords suggests that teachers should be alive to the fact that their autistic pupils may first process harmony when they hear a piece (rather than melody), with harmony providing the structural foundations upon which the memory of a piece is built (rather than the melody, which may well be the case for neurotypical pupils; it appears anecdotally that teachers frequently work on the 'right hand' part of pieces first before moving to the left). A further implication for teaching and learning is that it may well be the case that a savant pupil will learn more effectively by hearing and attempting to play a piece all the way through, rather than in small parts (as conventional music pedagogy suggests).

Finally, the research set out in this thesis is important as it demonstrates that investigations can be undertaken with people with learning difficulties can be ecologically valid without compromising rigour. Traditionally, cognitive psychology has tended to shy away from testing those with severe learning difficulties in a formal sense, since it has proved so difficult to obtain reliable data (or, in many cases, any data at all).

Nonetheless, there are a number of constraints with the approaches that have been taken here. Using musical responses to musical stimuli has its strengths as a methodology – but also has potential disadvantages. For example, having participants perform what they can hear inevitably adds a 'filter' to the responses; as we have seen above, errors in the chordal disaggregation task may have been due to technical limitations rather than cognitive ones. Also, having participants in the memory tests recall what they can at various stages means that interference was inevitable. Yet, without having recall at regular times, we would be unable to have any idea of the cognitive processes involved in learning and memory. One area of future research would be to have DP learn other pieces, but without attempting to play them for different lengths of time in the learning period, in an effort to ascertain the impact that the interference of performance may have. However, this would represent another large scale research effort.

In conclusion, I believe my study is of interest not only for the light it sheds on exceptional musicians, but on the musical mind in general. This is because, although DP has exceptional skills, the way he approaches music – non-conceptually, and without notation – is in some ways more like a 'typical' Western consumer of music, whose understanding is almost entirely intuitive.

Further work needs to be done on adapting some of the methods applied here (perhaps by having participants sing or tap responses rather than play them on the piano) to a 'neurotypical' population.

In summary my findings suggest that:

(a) musical savants are indeed exceptional in the way they process musical sounds; for example, they seem to have the ability to hear and identify many notes at the same time;

(b) the level of such abilities varies from one savant to another;

(c) some of the strategies that savants use, such as listening to chords from the 'bottom up' (from the lowest note to the highest) are also used by those so-called 'neurotypical' musicians with AP who have the most advanced auditory abilities;

(d) musical savants can learn complex music intuitively, and often without the assistance of a teacher; they appear to have an understanding of how pieces are structured, without making use of the taught, conscious strategies that most 'neurotypical' musicians adopt (in this respect they seem similar to young children, who can learn many songs just by listening and joining in);

(e) the abilities of musical savants appear to be 'encapsulated' in the brain; the skills in one auditory domain (music) do not transfer to another (processing spoken language).

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Appendix I:
Ethical procedure

Attachment 1:

Annamaria Mazzeschi
Institute of Education
20 Bedford Way
London WC1 H 0AL
Phone: 0207612 6000
Mobile: 07942551785
E-mail: amazzeschi@ioe.ac.uk

Date: 13 January 2009

Dear Derek,

Hello! This is Annamaria Mazzeschi writing to you.

I hope you are well.

Adam and I would like to test your memory again, like you have been doing over the years with the "Chromatic Blues". I know you've had fun doing that – and even went to Portugal with Adam to tell people about it! This time we would like you to see how good you are at learning a short story. We hope that what we find out may help the people who work with you to do it even better, and – because you have such a good memory – help people like me understand how everyone's memory works and how we could all learn things better.

The idea would be for me, Annamaria, to come to see you twice a week at Cunliffe House for two weeks, then we'd have a month off, then I'd come to see you twice a week for another two weeks. After that, it would be good to see how your memory of the story is getting on after three months, then again after sixth months. I could come at times that would suit you.

What I'd like to do, every time we meet, is to play you a recording of a short story and then ask you to tell it back to me. I'd make a tape of what we do, to help me understand how your memory is working, though I wouldn't play it to anyone else without asking you first.

Also, just for fun, I'd bring some CDs for us to listen to, and perhaps you'd like to play the piano too.

Perhaps you would like to talk about this plan with your family, with Vicky, your advocate, and with the staff at Cunliffe, to see if you would like take part. If you decide you don't want to, that's absolutely fine, and even if you do say 'yes' now, you can change your mind later and say 'no' whenever you want including when we are working together. All you would have to do is to say I've had enough now! And we will stop I really want you to enjoy what we do.

Could you ask someone to help you phone, write or email me on the contact details above to let me know what you have decided?

Many thanks
And all the best,
Annamaria Mazzeschi

Attachment 2:

Annamaria Mazzeschi

Institute of Education

20 Bedford Way

London WC1 H 0AL

Phone: 0207612 6000

Mobile: 07942551785

E-mail: amazzeschi@ioe.ac.uk

Date: 13 January 2009

Dear Sir/Madam

I would like to introduce myself. I am Annamaria Mazzeschi, a doctoral student at the Institute of Education, University of London. I am proposing to undertake research with people who are visually impaired, have learning difficulties and exceptional musical abilities. My intention is that in the long term my research will benefit people who are in this position by providing their teachers and cares with more effective strategies for supporting them.

To achieve this, with [participant's name] consent I would like to find out more about how he/she learns and remembers music and language, relates to other people and manages day-to day life. For your information I attach the Institute of Education Ethical Consent Form, which has had the University Ethics Committee's approval.

My plan is to visit [x] once or twice a week and utilizing some psychological tests such as WAIS, Vineland (Adaptive Behavior Interview) and a memory assessment

administer the test, and if s/he does not wish to participate, I will stop immediately. At the end of the test, I will spend a couple of hours with her/him listening and playing music together.

This could be an enjoyable experience for the participant.

In accordance with Data Protection Act (1998) all the research data that I will gather (essentially observational data, test results, supported by occasional video for detailed analysis at the Institute) is to be treated as confidential and anonymous. Copies of any written texts will be made available on request at any stage of the research process.

The Participant and his/her representative will be informed of the findings at the conclusion of the research in a way that is accessible to them, and he/she will be offered copies of any published materials in advance of publication.

Anonymity will be maintained in all dissemination of the research findings except where the participant positively indicates that they wish to be identified.

Copies of any written texts will be made available on request at any stage of the research process. The participants at Cunliffe House, Redhill has the formal right to withdraw from the research at any time, in accordance with our guidance of best practice from the British Educational Research Association (BERA) in their Ethical Guidelines (2004) and the Mental capacity Act (2005). A policy of 'voluntary informed consent' is being followed.

I hope that at the end of my research the information I gather and formulate into my thesis would become useful in establishing better understanding of musical savants, their psychological make-up, cognitive and social styles and above all their musical talents. Perhaps giving others the knowledge of what these unique individuals can contribute to society with their talents.

If for any reason, I notice that they are not enjoying the experience, or they have become tired I will stop the experiment immediately.

As the advocate for the participant (participant's name) I would like your formal consent to start this research project.

I look forward to hearing from you,

Yours faithfully,

Annamaria Mazzeschi

Attachment 3:

Institute of Education, University of London

An exploration of the abilities of musical savants

Doctoral Research Project

by

Annamaria Mazzeschi

Institute of Education

20 Bedford Way

London WC1 H 0AL

Phone: 0207612 6000

Mobile: 07942-551785

E-mail: amazzeschi@ioe.ac.uk

Annex 1

Example 1: Memory test

It is intended that the first session of the memory experiment will go as follows:

- The participant listens to a recording of the story
- recalls as much of the story as s/he can
- listens to the recording of the story again

In the second session, and all sessions after that, the protocol is planned to be as follows:

- The participant recalls as much of the story as s/he can
- listens to the recording of the story
- recalls as much of the story as s/he can

- listens to the recording of the story again

It is anticipated that each memory session will last between five and 10 minutes.

Once the formal part of the session is over, the researcher will offer to engage with the participant in an activity of his/her choice, purely for pleasure.

Attachment 4:

Outline of the project.

The aim of the research is to learn more about people who have exceptional musical abilities in the context of learning difficulties – so-called 'musical savants' – (Cowan, 2001; Hermelin et al. 1987; Mazzeschi et al., 2007; Miller 1989; Miller 1998; Treffert, 2000) with a view to developing tools for assessment and teaching that may assist practitioners working in the field, now and in the future.

For more than 200 years, numerous reports, observations and researches has been conducted into savant conditions, however there has been no concrete agreement on the condition known as savantism, due to the fact that there are no standard criteria for evaluating this condition.

The American Psychological Association (APA) Dictionary defines idiot savant as "a person with mental retardation who possesses a remarkable, highly developed ability or talent in one area, such as rapid calculation, expertise in playing music, or feats of memory. Such people are rare, and this ability usually occurs in those with mild or moderate mental retardation, with or without Autism Spectrum Disorders."

It further defines savant as "a learned individual, or an individual who demonstrates exceptional or remarkable and unusual intellectual prowess or skills or a person with mental retardation or an autistic spectrum disorder who demonstrates exceptional, usually isolated, cognitive abilities."

Although the 'savant phenomenon' is familiar to the general public through the frequent media exposure of certain individuals, there is still relatively little known about their special abilities, often without them having a conceptual understanding of what they are doing, and there remain few teaching strategies to support them in their learning. In fact in the literature there are many definitions of the phenomenon, but what we do not have is a formal description of the things that they are able to do and how their unexpected talent can really help to improve their quality of life and well-being.

Is their talent just an enjoyable activity for them or can it truly become a landmark and a resource through which we can start to progress towards a wider development?

How can their talent make them autonomous and increase their self esteem?

How and at what level their ability help and support them in terms of learning processes and increase their social communication?

These are all the questions this research project will endeavour to answer.

A protocol will be written in order to understand how they are able to function within their talent and in other areas. And how through working with their talent are they able to make their skills transferable

Building on previous work in the field (for example, Ockelford and Pring, 2005), the aims of the research are:

- to gather information about the research participants: their musical backgrounds, experiences and abilities, the nature of their disabilities and day-to-day lives, and how their areas of ability and disability interrelate;
- to develop a protocol for describing, understanding and comparing the special capabilities and needs of musical savants;
- to formulate pedagogical interventions that will assist in teaching and learning – both intrinsically musical and using music to promote wider development.

Data will be collected through:

- Interactions with savants.

- Discussion / informal interviews with their families and carers concerning the participant's history, day-to-day life and development - discussions that will be recorded with permission.

- Observations undertaken discreetly, although participants will always be informed when they are being observed and what the general nature of the observations is.

- Where appropriate, standardised tests will be administered to the savants by appropriately qualified members of the team.

- Custom-designed measures, such as absolute pitch tests, musical and non-musical memory tests and short learning programmes, which will always be approved in advance at Professorial level.

The research team comprises:

- Annamaria Mazzeschi, a doctoral student at the Institute of Education, with a background in music, and a qualified clinical psychologist from Italy, recently having completed her clinical training in Florence.
- Adam Ockelford, Professor of Music at the University of Roehampton, and a qualified teacher of the visually impaired, who has a great deal of experience of working with young people and adults with learning difficulties, and an internationally recognised track-record of research in this field.
- Graham Welch, Professor of Music Education at the Institute of Education, internationally recognised as a leading figure in music education research, with a good deal of recent experience in investigating the musical development of children and young people with learning difficulties.

The majority of the data collection will be undertaken by Annamaria Mazzeschi, with Professor Ockelford's direct involvement and supervision.

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Psicologo Dott. ssa Annamaria Mazzeschi

Iscrizione all'albo n. 47087

Io sottoscritto

ALBERTO NARETTO

nato a RIVAROLO (TO) il 25-11-1944

Mi impegno a dare il consenso per la raccolta dati per finalità di ricerca.

Il presente lavoro di ricerca ha come obiettivi lo studio del ruolo della musica nello sviluppo socio affettivo e l'analisi dei processi di memoria coinvolti nell'apprendimento musicale in soggetti con disturbo dello spettro autistico.

Sono di seguito riportati gli articoli del Codice Deontologico degli Psicologi Italiani (Testo approvato dal Consiglio Nazionale dell'Ordine nell'adunanza del 23 settembre 2006) che tutelano il lavoro di ricerca e prevedono nel ruolo dello Psicologo competenze sia cliniche che di ricerca.

Articolo 7

Nelle proprie attività professionali, nelle attività di ricerca e nelle comunicazioni dei risultati delle stesse, nonché nelle attività didattiche, lo psicologo valuta attentamente, anche in relazione al contesto, il grado di validità e di attendibilità di informazioni, dati e fonti su cui basa le conclusioni raggiunte; espone, all'occorrenza, le ipotesi interpretative alternative, ed esplicita i limiti dei risultati. Lo psicologo, su *casi specifici, esprime valutazioni e giudizi professionali solo se fondati sulla conoscenza* professionale diretta ovvero su una documentazione adeguata ed attendibile.

Articolo 9

Nella sua attività di ricerca lo psicologo è tenuto ad informare adeguatamente i soggetti in essa coinvolti al fine di ottenerne il previo consenso informato, anche relativamente al nome, allo status scientifico e professionale del ricercatore ed alla sua eventuale istituzione di appartenenza. Egli deve altresì garantire a tali soggetti la piena libertà di concedere, di rifiutare ovvero di ritirare il consenso stesso.

Nell' ipotesi in cui la natura della ricerca non consenta di informare preventivamente e correttamente i soggetti su taluni aspetti della ricerca stessa, lo psicologo ha l'obbligo di fornire comunque, alla fine della prova ovvero della raccolta dei dati, le informazioni dovute e di ottenere l'autorizzazione all'uso dei dati raccolti. Per quanto concerne i soggetti che, per età o per altri motivi, non sono in grado di esprimere validamente il loro consenso, questo deve essere dato da chi ne ha la potestà genitoriale o la tutela, e, altresì, dai soggetti stessi, ove siano in grado di comprendere la natura della collaborazione richiesta.

Deve essere tutelato, in ogni caso, il diritto dei soggetti alla riservatezza, alla non riconoscibilità ed all'anonimato.

La ricerca verrà effettuata dalla Psicologa Dott. ssa Annamaria Mazzeschi in collaborazione con la Professoressa Annamaria Bordin.

Con la presente dichiaro di essere stato informato degli obiettivi dello studio e do la mia autorizzazione per l'utilizzo dei dati che verranno raccolti, strettamente per scopi di ricerca scientifica.

Firme

Translation of the consent form for GN's parents:

Annamaria Mazzeschi, Clinical Psychologist (qualified by the Italian Psychological Association)
Registration Number: 47087

(Name) Alberto Naretto___________________________________

(city of birth) _______Rivarolo_________date of birth __25/11/1944_____

I give consent for my son Gabriele Naretto to be included in the data collection for research purposes.

The objectives of this research are to investigate the perception, learning and memory processes in people on the autism spectrum condition. Furthermore, the project explores the role that music plays in their daily lives.

Annamaria Mazzeschi will follow the Deontological Code of the Italian Psychologist, which classifies and approves the competences of the Psychologists for both clinical and research work.

The research will be carried out by Annamaria Mazzeschi in collaboration with Prof Annamaria Bordin.

With this form I state that I have been informed about the objectives of the study and I will give my authorisation for the use of the data that will be gathered for scientific research.

Appendix II:
Probability calculations:
model for 7 notes

Expand n maps onto n, n maps onto n-1, n is greater than or equal to 0

1 note	2 notes	3 notes	4 notes	5 notes	6 notes	7 notes
25	**24**	**23**	**22**	**21**	**20**	**19**
7	6	5	4	3	0	0
	7	6	5	4	3	2
		6	5	4	3	2
		7	6	5	4	3
			5	4	3	2
			6	5	4	3
			6	5	4	3
			7	6	5	4
				4	3	2
				5	4	3
				5	4	3
				6	5	4
				5	4	3
				6	5	4
				6	5	4
				7	6	5
					3	2
					4	3
					4	3
					5	4
					4	3
					5	4
					5	4
					6	5
					4	3
					5	4
					5	4

1 note	2 notes	3 notes	4 notes	5 notes	6 notes
25	**24**	**23**	**22**	**21**	**20**
0.2800	0.2500	0.2174	0.1818	0.1429	0.0000
0.7200	0.7500	0.7826	0.8182	0.8571	1.0000
	0.2917	0.2609	0.2273	0.1905	0.1500
	0.7083	0.7391	0.7727	0.8095	0.8500
		0.2609	0.2273	0.1905	0.1500
		0.7391	0.7727	0.8095	0.8500
		0.3043	0.2727	0.2381	0.2000
		0.6957	0.7273	0.7619	0.8000
			0.2273	0.1905	0.1500
			0.7727	0.8095	0.8500
			0.2727	0.2381	0.2000
			0.7273	0.7619	0.8000
			0.2727	0.2381	0.2000
			0.7273	0.7619	0.8000
			0.3182	0.2857	0.2500
			0.6818	0.7143	0.7500
				0.1905	0.1500
				0.8095	0.8500
				0.2381	0.2000
				0.7619	0.8000
				0.2381	0.2000
				0.7619	0.8000
				0.2857	0.2500
				0.7143	0.7500
				0.2381	0.2000
				0.7619	0.8000
				0.2857	0.2500
				0.7143	0.7500
				0.2857	0.2500
				0.7143	0.7500
				0.3333	0.3000
				0.6667	0.7000
					0.1500
					0.8500
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					0.8000
					0.2000
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					0.7500
					0.2500
					0.7500

6	5	0.3000
		0.7000
5	4	0.2500
		0.7500
6	5	0.3000
		0.7000
6	5	0.3000
		0.7000
7	6	0.3500
		0.6500
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6 4 5 5 6 5 6 6 7

7 notes 19	1 note 25	2 notes 24	3 notes 23	4 notes 22	5 notes 21	6 notes 20	7 notes 19	no correct						
0.0000	0.2800	0.2500	0.2174	0.1818	0.1429	0.0000	0.0000	7	7	7	7	7	7	7
1.0000	0.2800	0.2500	0.2174	0.1818	0.1429	0.0000	1.0000		6	6	6	6	6	6
0.1053	0.2800	0.2500	0.2174	0.1818	0.1429	1.0000	0.0000			6	6	6	6	6
0.8947	0.2800	0.2500	0.2174	0.1818	0.1429	1.0000	1.0000			5	5	5	5	5
0.1053	0.2800	0.2500	0.2174	0.1818	0.8571	0.1500	0.0000				6	6	6	6
0.8947	0.2800	0.2500	0.2174	0.1818	0.8571	0.1500	1.0000				5	5	5	5
0.1579	0.2800	0.2500	0.2174	0.1818	0.8571	0.8500	0.0526				5	5	5	5
0.8421	0.2800	0.2500	0.2174	0.1818	0.8571	0.8500	0.9474				4	4	4	4
0.1053	0.2800	0.2500	0.2174	0.8182	0.1905	0.1500	0.0000					6	6	6
0.8947	0.2800	0.2500	0.2174	0.8182	0.1905	0.1500	1.0000					5	5	5
0.1579	0.2800	0.2500	0.2174	0.8182	0.1905	0.8500	0.0526					5	5	5
0.8421	0.2800	0.2500	0.2174	0.8182	0.1905	0.8500	0.9474					4	4	4
0.1579	0.2800	0.2500	0.2174	0.8182	0.8095	0.2000	0.0526					5	5	5
0.8421	0.2800	0.2500	0.2174	0.8182	0.8095	0.2000	0.9474					4	4	4
0.2105	0.2800	0.2500	0.2174	0.8182	0.8095	0.8000	0.1053					4	4	4
0.7895	0.2800	0.2500	0.2174	0.8182	0.8095	0.8000	0.8947					3	3	3
0.1053	0.2800	0.2500	0.7826	0.2273	0.1905	0.1500	0.0000						6	6
0.8947	0.2800	0.2500	0.7826	0.2273	0.1905	0.1500	1.0000						5	5
0.1579	0.2800	0.2500	0.7826	0.2273	0.1905	0.8500	0.0526						5	5
0.8421	0.2800	0.2500	0.7826	0.2273	0.1905	0.8500	0.9474						4	4
0.1579	0.2800	0.2500	0.7826	0.2273	0.8095	0.2000	0.0526						5	5
0.8421	0.2800	0.2500	0.7826	0.2273	0.8095	0.2000	0.9474						4	4
0.2105	0.2800	0.2500	0.7826	0.2273	0.8095	0.8000	0.1053						4	4
0.7895	0.2800	0.2500	0.7826	0.2273	0.8095	0.8000	0.8947						3	3
0.1579	0.2800	0.2500	0.7826	0.7727	0.2381	0.2000	0.0526						5	5
0.8421	0.2800	0.2500	0.7826	0.7727	0.2381	0.2000	0.9474						4	4
0.2105	0.2800	0.2500	0.7826	0.7727	0.2381	0.8000	0.1053						4	4
0.7895	0.2800	0.2500	0.7826	0.7727	0.2381	0.8000	0.8947						3	3
0.2105	0.2800	0.2500	0.7826	0.7727	0.7619	0.2500	0.1053						4	4
0.7895	0.2800	0.2500	0.7826	0.7727	0.7619	0.2500	0.8947						3	3
0.2632	0.2800	0.2500	0.7826	0.7727	0.7619	0.7500	0.1579						3	3
0.7368	0.2800	0.2500	0.7826	0.7727	0.7619	0.7500	0.8421						2	2
0.1053	0.2800	0.7500	0.2609	0.2273	0.1905	0.1500	0.0000							6
0.8947	0.2800	0.7500	0.2609	0.2273	0.1905	0.1500	1.0000							5
0.1579	0.2800	0.7500	0.2609	0.2273	0.1905	0.8500	0.0526							5
0.8421	0.2800	0.7500	0.2609	0.2273	0.1905	0.8500	0.9474							4
0.1579	0.2800	0.7500	0.2609	0.2273	0.8095	0.2000	0.0526							5
0.8421	0.2800	0.7500	0.2609	0.2273	0.8095	0.2000	0.9474							4
0.2105	0.2800	0.7500	0.2609	0.2273	0.8095	0.8000	0.1053							4
0.7895	0.2800	0.7500	0.2609	0.2273	0.8095	0.8000	0.8947							3
0.1579	0.2800	0.7500	0.2609	0.7727	0.2381	0.2000	0.0526							5
0.8421	0.2800	0.7500	0.2609	0.7727	0.2381	0.2000	0.9474							4
0.2105	0.2800	0.7500	0.2609	0.7727	0.2381	0.8000	0.1053							4
0.7895	0.2800	0.7500	0.2609	0.7727	0.2381	0.8000	0.8947							3
0.2105	0.2800	0.7500	0.2609	0.7727	0.7619	0.2500	0.1053							4
0.7895	0.2800	0.7500	0.2609	0.7727	0.7619	0.2500	0.8947							3
0.2632	0.2800	0.7500	0.2609	0.7727	0.7619	0.7500	0.1579							3
0.7368	0.2800	0.7500	0.2609	0.7727	0.7619	0.7500	0.8421							2
0.1579	0.2800	0.7500	0.7391	0.2727	0.2381	0.2000	0.0526							5
0.8421	0.2800	0.7500	0.7391	0.2727	0.2381	0.2000	0.9474							4
0.2105	0.2800	0.7500	0.7391	0.2727	0.2381	0.8000	0.1053							4
0.7895	0.2800	0.7500	0.7391	0.2727	0.2381	0.8000	0.8947							3
0.2105	0.2800	0.7500	0.7391	0.2727	0.7619	0.2500	0.1053							4
0.7895	0.2800	0.7500	0.7391	0.2727	0.7619	0.2500	0.8947							3

0.2632	0.2800	0.7500	0.7391	0.2727	0.7619	0.7500	0.1579	3
0.7368	0.2800	0.7500	0.7391	0.2727	0.7619	0.7500	0.8421	2
0.2105	0.2800	0.7500	0.7391	0.7273	0.2857	0.2500	0.1053	4
0.7895	0.2800	0.7500	0.7391	0.7273	0.2857	0.2500	0.8947	3
0.2632	0.2800	0.7500	0.7391	0.7273	0.2857	0.7500	0.1579	3
0.7368	0.2800	0.7500	0.7391	0.7273	0.2857	0.7500	0.8421	2
0.2632	0.2800	0.7500	0.7391	0.7273	0.7143	0.3000	0.1579	3
0.7368	0.2800	0.7500	0.7391	0.7273	0.7143	0.3000	0.8421	2
0.3158	0.2800	0.7500	0.7391	0.7273	0.7143	0.7000	0.2105	2
0.6842	0.2800	0.7500	0.7391	0.7273	0.7143	0.7000	0.6842	1
0.0000	0.7200	0.2917	0.2609	0.2273	0.1905	0.1500	0.0000	
1.0000	0.7200	0.2917	0.2609	0.2273	0.1905	0.1500	1.0000	
0.1579	0.7200	0.2917	0.2609	0.2273	0.1905	0.8500	0.1579	
0.8421	0.7200	0.2917	0.2609	0.2273	0.1905	0.8500	0.8421	
0.1579	0.7200	0.2917	0.2609	0.2273	0.8095	0.2000	0.1579	
0.8421	0.7200	0.2917	0.2609	0.2273	0.8095	0.2000	0.8421	
0.2105	0.7200	0.2917	0.2609	0.2273	0.8095	0.8000	0.2105	
0.7895	0.7200	0.2917	0.2609	0.2273	0.8095	0.8000	0.7895	
0.1579	0.7200	0.2917	0.2609	0.7727	0.2381	0.2500	0.1579	
0.8421	0.7200	0.2917	0.2609	0.7727	0.2381	0.2500	0.8421	
0.2105	0.7200	0.2917	0.2609	0.7727	0.2381	0.7500	0.2105	
0.7895	0.7200	0.2917	0.2609	0.7727	0.2381	0.7500	0.7895	
0.2105	0.7200	0.2917	0.2609	0.7727	0.7619	0.2500	0.2105	
0.7895	0.7200	0.2917	0.2609	0.7727	0.7619	0.2500	0.7895	
0.2632	0.7200	0.2917	0.2609	0.7727	0.7619	0.7500	0.2632	
0.7368	0.7200	0.2917	0.2609	0.7727	0.7619	0.7500	0.7368	
0.1579	0.7200	0.2917	0.7391	0.2727	0.2381	0.2500	0.1579	
0.8421	0.7200	0.2917	0.7391	0.2727	0.2381	0.2500	0.8421	
0.2105	0.7200	0.2917	0.7391	0.2727	0.2381	0.7500	0.2105	
0.7895	0.7200	0.2917	0.7391	0.2727	0.2381	0.7500	0.7895	
0.2105	0.7200	0.2917	0.7391	0.2727	0.7619	0.2500	0.2105	
0.7895	0.7200	0.2917	0.7391	0.2727	0.7619	0.2500	0.7895	
0.2632	0.7200	0.2917	0.7391	0.2727	0.7619	0.7500	0.2632	
0.7368	0.7200	0.2917	0.7391	0.2727	0.7619	0.7500	0.7368	
0.2105	0.7200	0.2917	0.7391	0.7273	0.2857	0.3000	0.2105	
0.7895	0.7200	0.2917	0.7391	0.7273	0.2857	0.3000	0.7895	
0.2632	0.7200	0.2917	0.7391	0.7273	0.2857	0.7000	0.2632	
0.7368	0.7200	0.2917	0.7391	0.7273	0.2857	0.7000	0.7368	
0.2632	0.7200	0.2917	0.7391	0.7273	0.7143	0.2000	0.2632	
0.7368	0.7200	0.2917	0.7391	0.7273	0.7143	0.2000	0.7368	
0.3158	0.7200	0.2917	0.7391	0.7273	0.7143	0.8000	0.3158	
0.6842	0.7200	0.2917	0.7391	0.7273	0.7143	0.8000	0.6842	
0.1579	0.7200	0.7083	0.3043	0.2727	0.2381	0.2500	0.1579	
0.8421	0.7200	0.7083	0.3043	0.2727	0.2381	0.2500	0.8421	
0.2105	0.7200	0.7083	0.3043	0.2727	0.2381	0.7500	0.2105	
0.7895	0.7200	0.7083	0.3043	0.2727	0.2381	0.7500	0.7895	
0.2105	0.7200	0.7083	0.3043	0.2727	0.7619	0.2500	0.2105	
0.7895	0.7200	0.7083	0.3043	0.2727	0.7619	0.2500	0.7895	
0.2632	0.7200	0.7083	0.3043	0.2727	0.7619	0.7500	0.2632	
0.7368	0.7200	0.7083	0.3043	0.2727	0.7619	0.7500	0.7368	
0.2105	0.7200	0.7083	0.3043	0.7273	0.2857	0.3000	0.2105	
0.7895	0.7200	0.7083	0.3043	0.7273	0.2857	0.3000	0.7895	
0.2632	0.7200	0.7083	0.3043	0.7273	0.2857	0.7000	0.2632	
0.7368	0.7200	0.7083	0.3043	0.7273	0.2857	0.7000	0.7368	
0.2632	0.7200	0.7083	0.3043	0.7273	0.7143	0.3000	0.2632	
0.7368	0.7200	0.7083	0.3043	0.7273	0.7143	0.3000	0.7368	

0.3158	0.7200	0.7083	0.3043	0.7273	0.7143	0.7000	0.3158
0.6842	0.7200	0.7083	0.3043	0.7273	0.7143	0.7000	0.6842
0.2105	0.7200	0.7083	0.6957	0.3182	0.2857	0.2500	0.2105
0.7895	0.7200	0.7083	0.6957	0.3182	0.2857	0.2500	0.7895
0.2632	0.7200	0.7083	0.6957	0.3182	0.2857	0.7500	0.2632
0.7368	0.7200	0.7083	0.6957	0.3182	0.2857	0.7500	0.7368
0.2632	0.7200	0.7083	0.6957	0.3182	0.7143	0.2500	0.2632
0.7368	0.7200	0.7083	0.6957	0.3182	0.7143	0.2500	0.7368
0.3158	0.7200	0.7083	0.6957	0.3182	0.7143	0.7500	0.3158
0.6842	0.7200	0.7083	0.6957	0.3182	0.7143	0.7500	0.6842
0.2632	0.7200	0.7083	0.6957	0.6818	0.3333	0.3000	0.2632
0.7368	0.7200	0.7083	0.6957	0.6818	0.3333	0.3000	0.7368
0.3158	0.7200	0.7083	0.6957	0.6818	0.3333	0.7000	0.3158
0.6842	0.7200	0.7083	0.6957	0.6818	0.3333	0.7000	0.6842
0.3158	0.7200	0.7083	0.6957	0.6818	0.6667	0.3000	0.3158
0.6842	0.7200	0.7083	0.6957	0.6818	0.6667	0.3000	0.6842
0.3684	0.7200	0.7083	0.6957	0.6818	0.6667	0.7000	0.3684
0.6316	0.7200	0.7083	0.6957	0.6818	0.6667	0.7000	0.6316

	7 attempts	6 attempts	5 attempts	4 attempts	3 attempts	2 attempts	1 attempt	no correct	**7 attempts**	
								7	6	5
7	0.0000							0.0000		
6	0.0000	0.0000							0.0000	
6	0.0000								0.0000	
5	0.0004	0.0004	0.0004							0.0004
6	0.0000								0.0000	
5	0.0004	0.0004								0.0004
5	0.0001									0.0001
4	0.0019	0.0020	0.0024	0.0028						
6	0.0000								0.0000	
5	0.0004	0.0004								0.0004
5	0.0001									0.0001
4	0.0019	0.0020	0.0024							
5	0.0001									0.0001
4	0.0019	0.0020								
4	0.0008									
3	0.0072	0.0081	0.0101	0.0125	0.0152					
6	0.0000								0.0000	
5	0.0004	0.0004								0.0004
5	0.0001									0.0001
4	0.0019	0.0020	0.0024							
5	0.0001									0.0001
4	0.0019	0.0020								
4	0.0008									
3	0.0072	0.0081	0.0101	0.0125						
5	0.0001									0.0001
4	0.0019	0.0020								
4	0.0008									
3	0.0072	0.0081	0.0101							
4	0.0008									
3	0.0072	0.0081								
3	0.0038									
2	0.0204	0.0242	0.0323	0.0423	0.0548	0.0700				
6	0.0000								0.0000	
5	0.0004	0.0004								0.0004
5	0.0001									0.0001
4	0.0019	0.0020	0.0024							
5	0.0001									0.0001
4	0.0019	0.0020								
4	0.0008									
3	0.0072	0.0081	0.0101	0.0125						
5	0.0001									0.0001
4	0.0019	0.0020								
4	0.0008									
3	0.0072	0.0081	0.0101							
4	0.0008									
3	0.0072	0.0081								
3	0.0038									
2	0.0204	0.0242	0.0323	0.0423	0.0548					
5	0.0001									0.0001
4	0.0019	0.0020								
4	0.0008									
3	0.0072	0.0081	0.0101							
4	0.0008									
3	0.0072	0.0081								

3	0.0038								
2	0.0204	0.0242	0.0323	0.0423					
4	0.0008								
3	0.0072	0.0081							
3	0.0038								
2	0.0204	0.0242	0.0323						
3	0.0038								
2	0.0204	0.0242							
2	0.0119								
1	0.0386	0.0564	0.0806	0.1129	0.1552	0.2100	0.2800		
6	0.0000							0.0000	
5	0.0004	0.0004							0.0004
5	0.0003								0.0003
4	0.0017	0.0020	0.0024						
5	0.0003								0.0003
4	0.0017	0.0020							
4	0.0017								
3	0.0064	0.0081	0.0101	0.0125					
5	0.0004								0.0004
4	0.0021	0.0025							
4	0.0016								
3	0.0060	0.0076	0.0101						
4	0.0017								
3	0.0064	0.0081							
3	0.0064								
2	0.0178	0.0242	0.0323	0.0423	0.0548				
5	0.0004								0.0004
4	0.0021	0.0025							
4	0.0016								
3	0.0060	0.0076	0.0101						
4	0.0017								
3	0.0064	0.0081							
3	0.0064								
2	0.0178	0.0242	0.0323	0.0423					
4	0.0020								
3	0.0076	0.0097							
3	0.0059								
2	0.0166	0.0226	0.0323						
3	0.0042								
2	0.0119	0.0161							
2	0.0204								
1	0.0441	0.0645	0.0806	0.1129	0.1552	0.2100			
5	0.0004								0.0004
4	0.0021	0.0025							
4	0.0016								
3	0.0060	0.0076	0.0101						
4	0.0017								
3	0.0064	0.0081							
3	0.0064								
2	0.0178	0.0242	0.0323	0.0423					
4	0.0020								
3	0.0076	0.0097							
3	0.0059								
2	0.0166	0.0226	0.0323						
3	0.0064								
2	0.0178	0.0242							

2	0.0178									
1	0.0386	0.0564	0.0806	0.1129	0.1552					
4	0.0017									
3	0.0064	0.0081								
3	0.0064									
2	0.0178	0.0242	0.0323							
3	0.0053									
2	0.0149	0.0202								
2	0.0191									
1	0.0414	0.0605	0.0806	0.1129						
3	0.0064									
2	0.0178	0.0242								
2	0.0178									
1	0.0386	0.0564	0.0806							
2	0.0153									
1	0.0331	0.0484								
1	0.0416									
0	0.0713	0.1129	0.1613	0.2419	0.3548	0.5100	0.7200			
							Count	1	7	21
							sums	0.0000	0.0000	0.0051

					no correct	**6 attempts**					
4	3	2	1	0	6	5	4	3	2	1	0
					0.0000						
						0.0004					
						0.0004					
0.0019							0.0020				
						0.0004					
0.0019							0.0020				
0.0019							0.0020				
0.0008											
	0.0072							0.0081			
						0.0004					
0.0019							0.0020				
0.0019							0.0020				
0.0008											
	0.0072							0.0081			
0.0019							0.0020				
0.0008											
	0.0072							0.0081			
0.0008											
	0.0072						0.0081				
	0.0038										
		0.0204							0.0242		
						0.0004					
0.0019							0.0020				
0.0019							0.0020				
0.0008											
	0.0072							0.0081			
0.0019							0.0020				
0.0008											
	0.0072							0.0081			
0.0008											
	0.0072							0.0081			
	0.0038										
		0.0204							0.0242		
0.0019							0.0020				
0.0008											
	0.0072							0.0081			
0.0008											
	0.0072							0.0081			

	0.0038							
		0.0204					0.0242	
0.0008								
	0.0072					0.0081		
	0.0038							
		0.0204					0.0242	
	0.0038							
		0.0204					0.0242	
		0.0119						
			0.0386					0.0564
				0.0004				
0.0017					0.0020			
0.0017					0.0020			
0.0017								
	0.0064					0.0081		
0.0021					0.0025			
0.0016								
	0.0060					0.0076		
0.0017								
	0.0064					0.0081		
	0.0064							
		0.0178					0.0242	
0.0021					0.0025			
0.0016								
	0.0060					0.0076		
0.0017								
	0.0064					0.0081		
	0.0064							
		0.0178					0.0242	
0.0020								
	0.0076					0.0097		
	0.0059							
		0.0166					0.0226	
	0.0042							
		0.0119					0.0161	
		0.0204						
			0.0441					0.0645
0.0021					0.0025			
0.0016								
	0.0060					0.0076		
0.0017								
	0.0064					0.0081		
	0.0064							
		0.0178					0.0242	
0.0020								
	0.0076					0.0097		
	0.0059							
		0.0166					0.0226	
	0.0064							
		0.0178					0.0242	

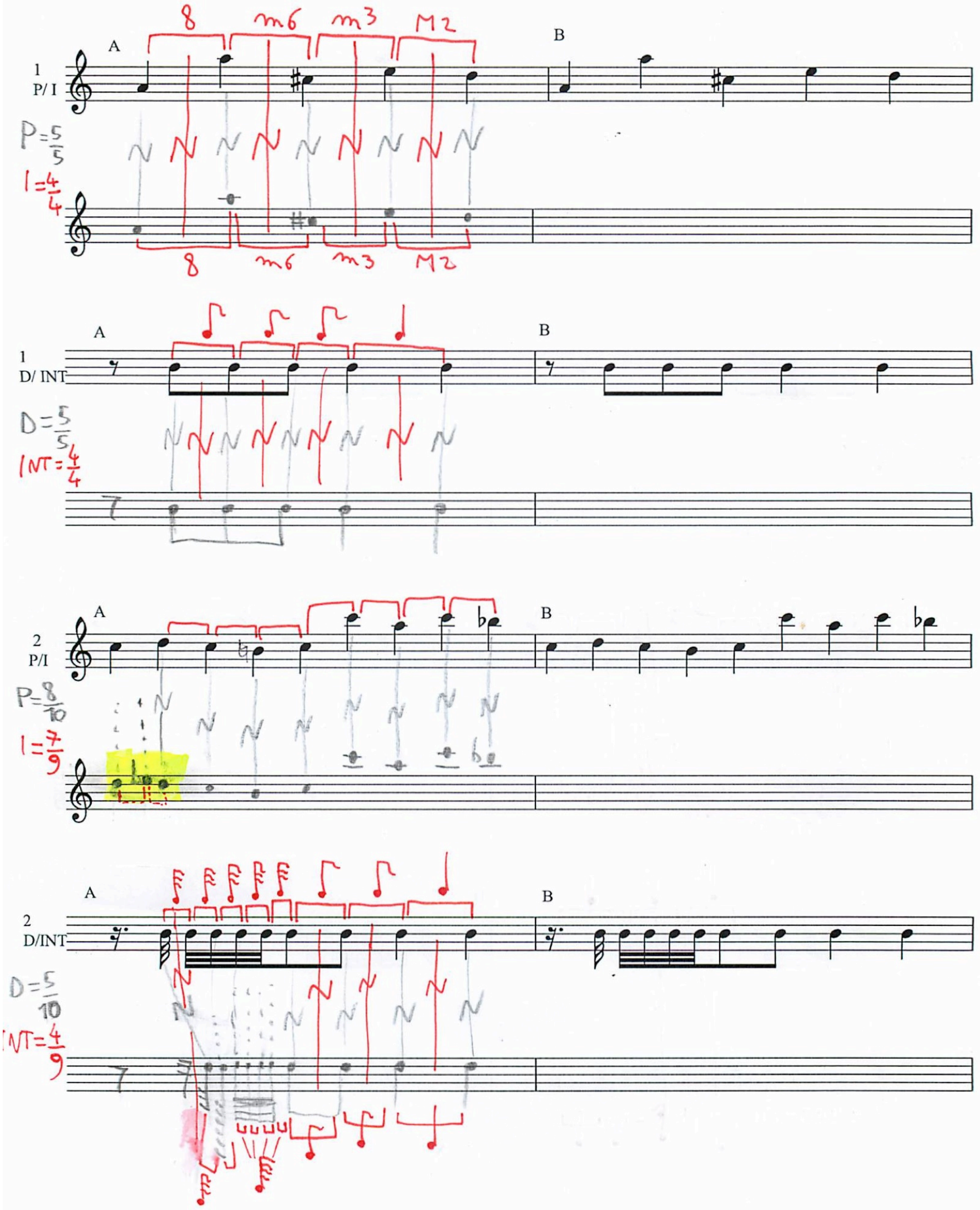
		0.0178											
			0.0386								0.0564		
0.0017													
	0.0064								0.0081				
	0.0064												
		0.0178								0.0242			
	0.0053												
		0.0149								0.0202			
		0.0191											
			0.0414								0.0605		
	0.0064												
		0.0178								0.0242			
		0.0178											
			0.0386								0.0564		
		0.0153											
			0.0331								0.0484		
			0.0416										
				0.0713								0.1129	
35	35	21	7	1	**128**	1	6	16	19	15	6	1	**63**
0.0547	0.2159	0.3711	0.2761	0.0713	**0.99**	0.0000	0.0022	0.0398	0.1549	0.3475	0.3427	0.1129	**1.00**

Appendix III:
Extract from the *Classical Turn* analysis

TRIAL 1

date: 2009/07/14 top

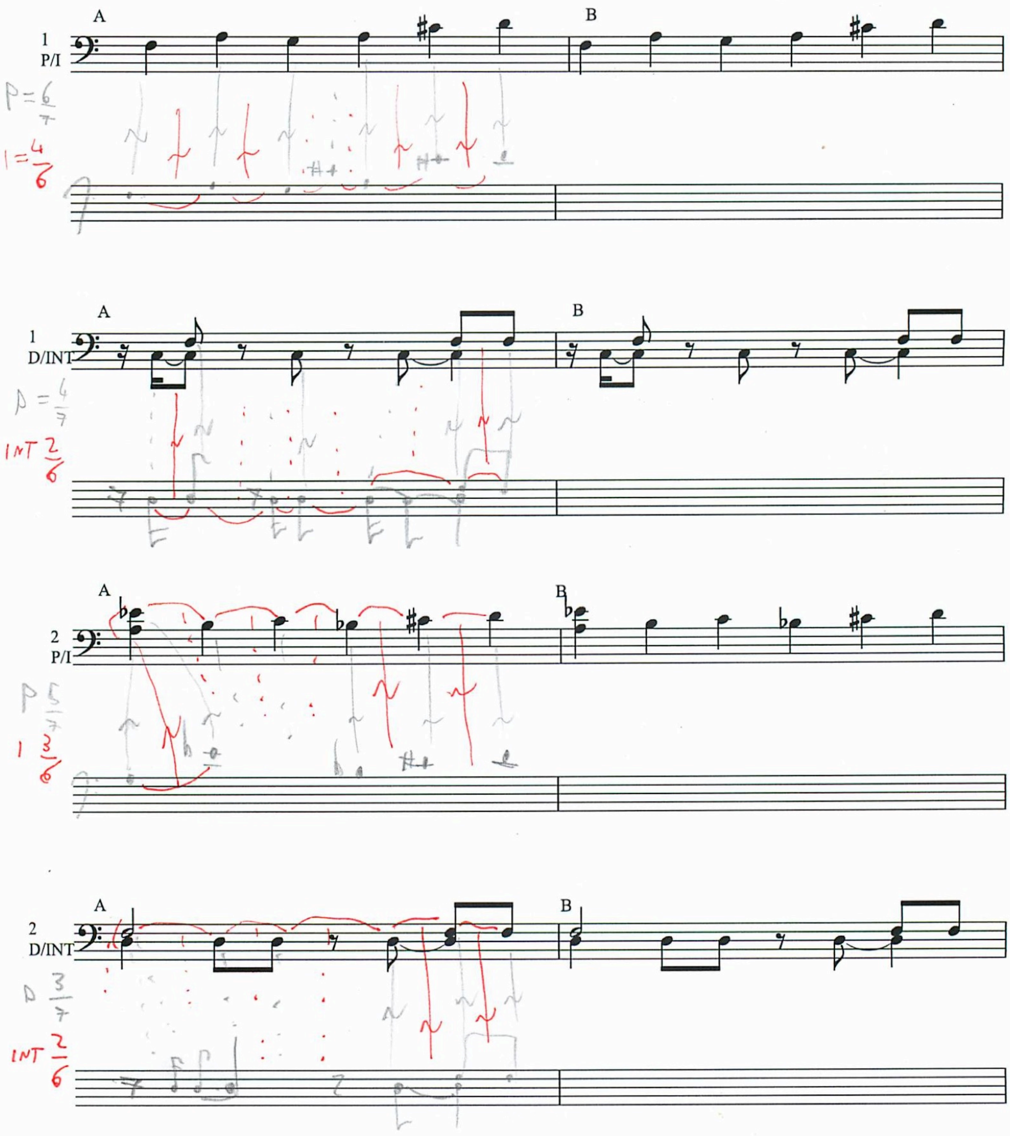
bar:1-2



TRIAL 4

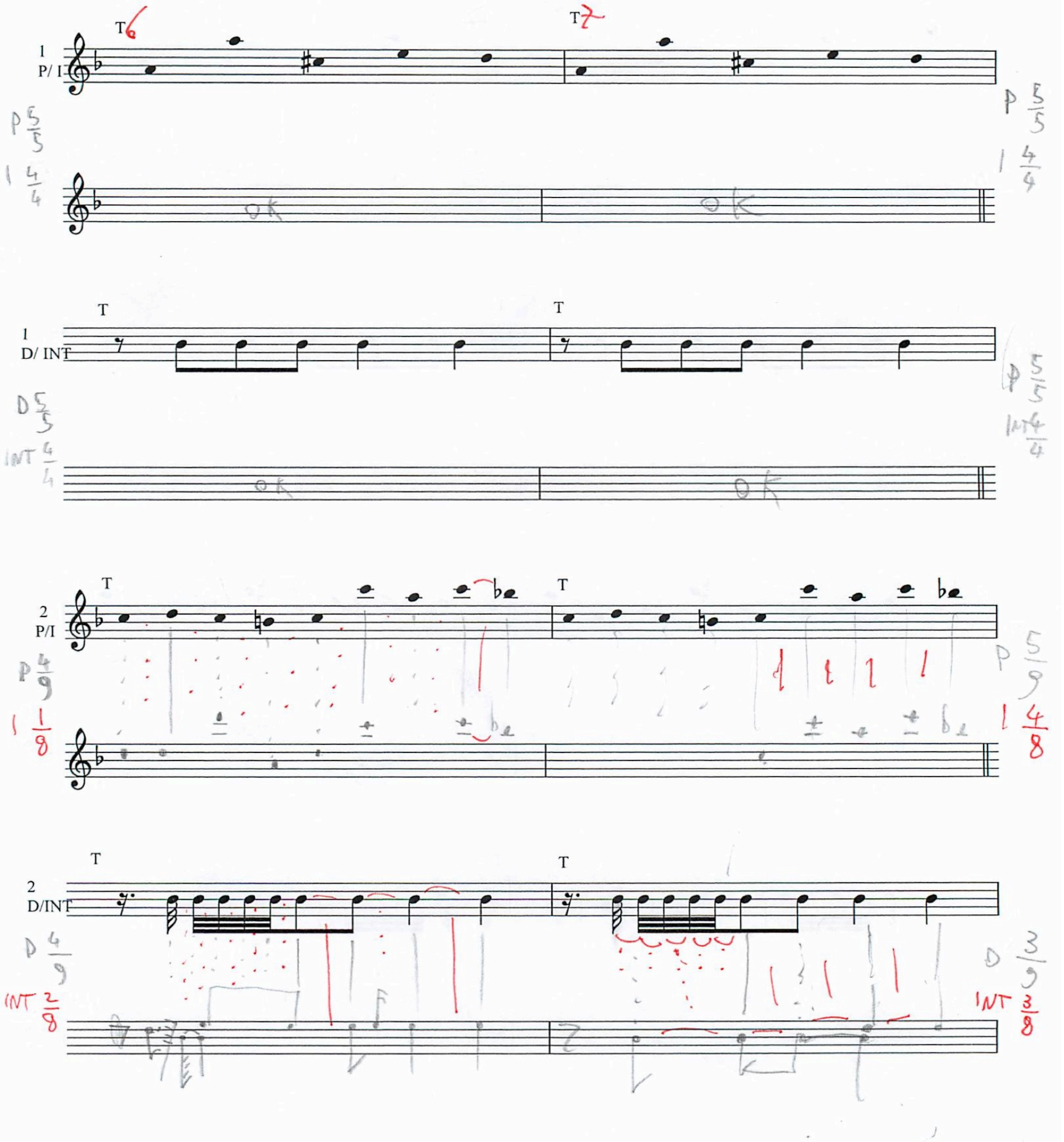
date: 2009/7/14 middle

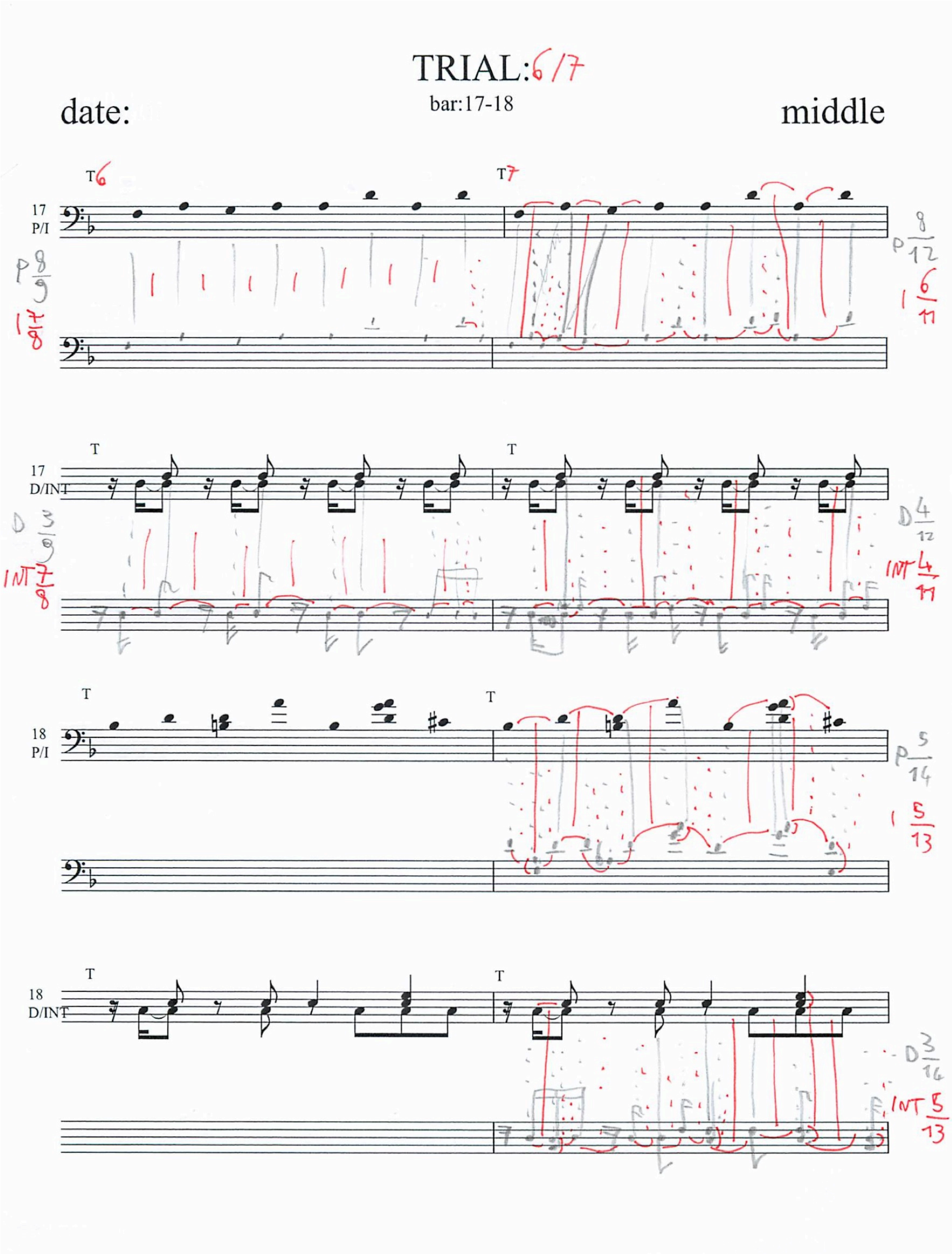
bar:1-2



TRIAL: 6/7

date: bar:1-2 top



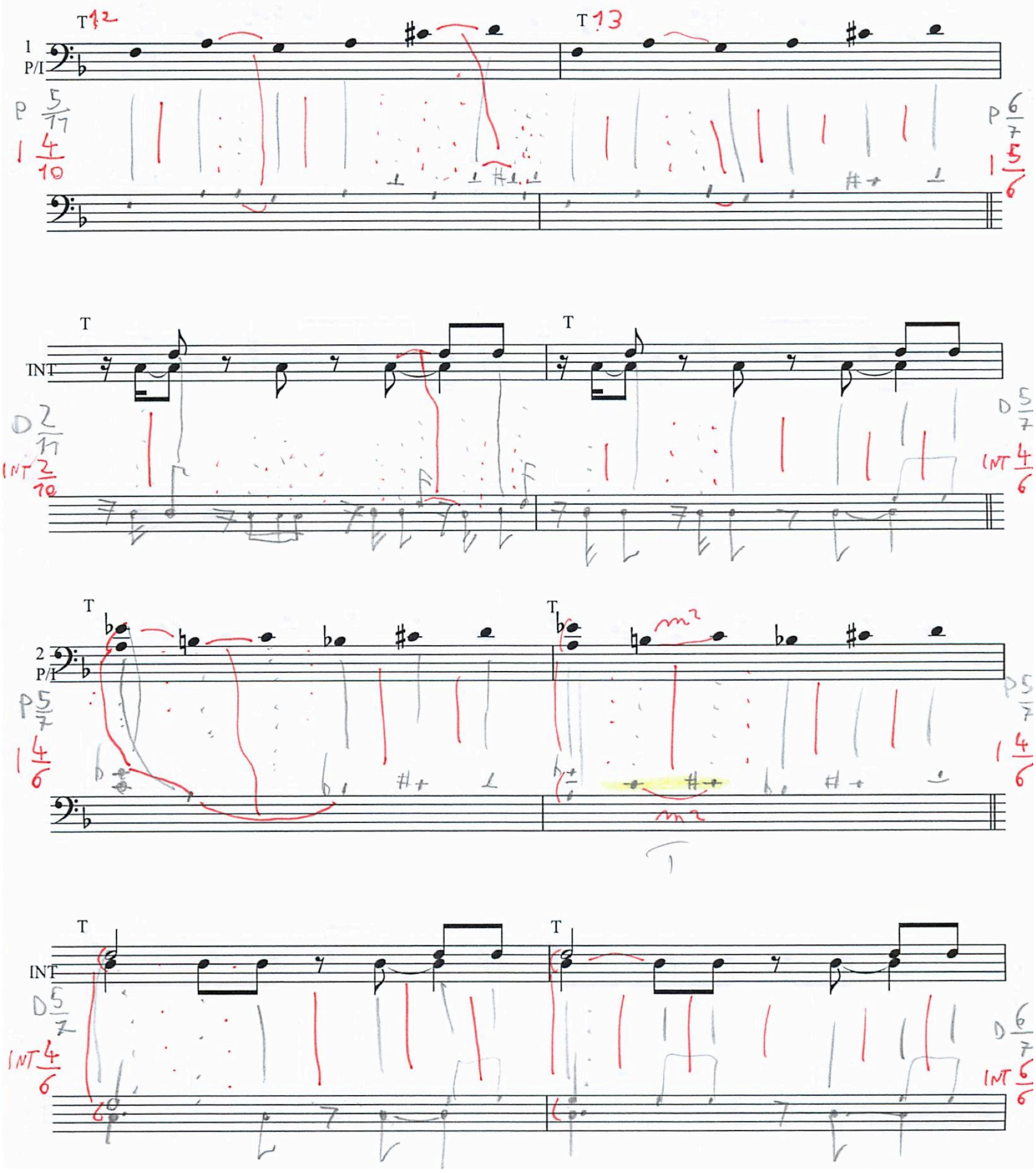

TRIAL:6/7
date:
bar:17-18
middle
T6
T7
17
P/I
P 8/9
I 7/8
P 8/12
I 6/11
T
17
D/INT
D 3/9
INT 7/8
D 4/12
INT 4/11
T
18
P/I
P 5/14
I 5/13
T
18
D/INT
D 3/16
INT 5/13

TRIAL: 10/11

date: bar:17-18 bottom

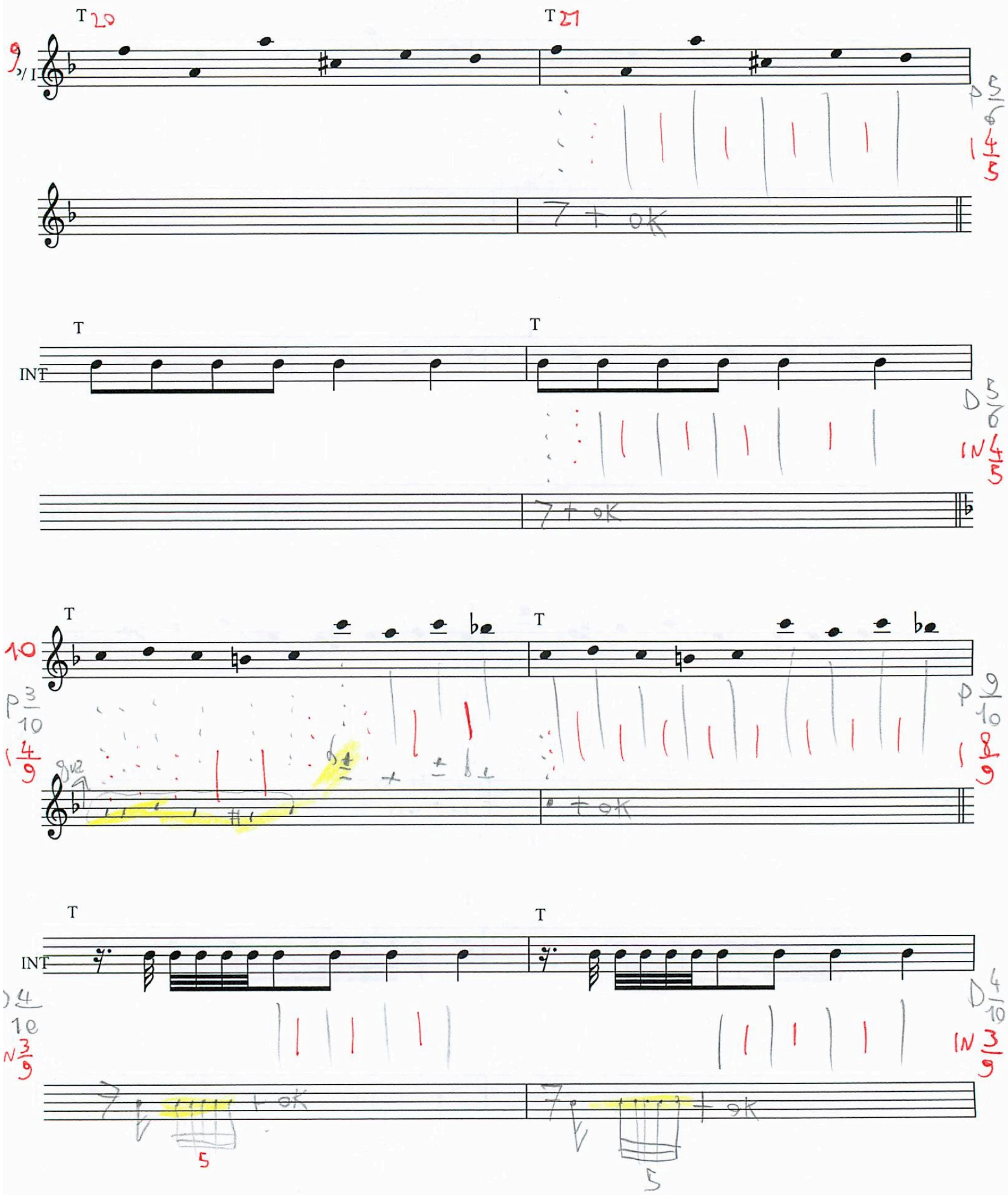
TRIAL: 12/13

date: bar:1-2 middle



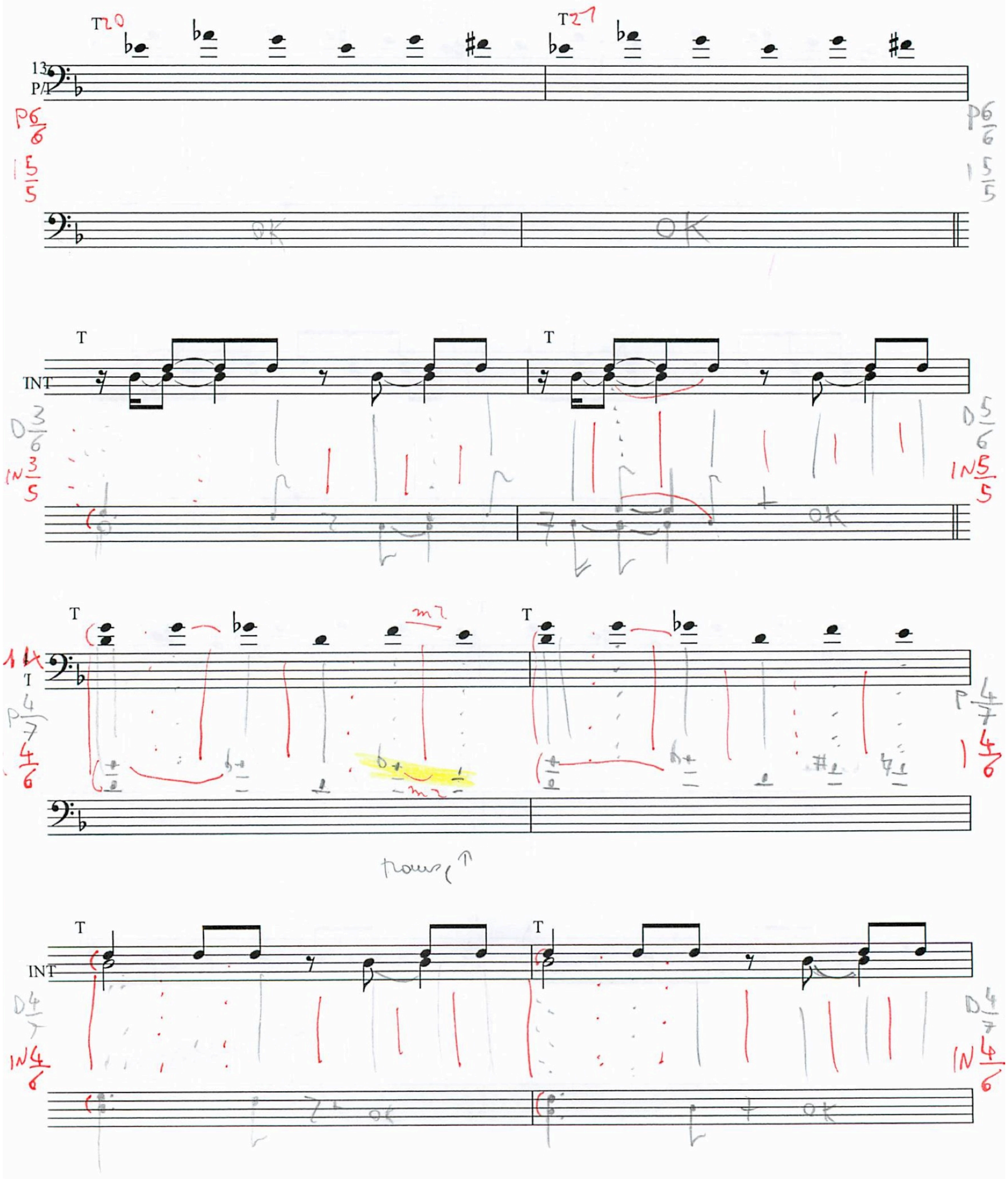
TRIAL: 20/21

date: bar:9-10 top



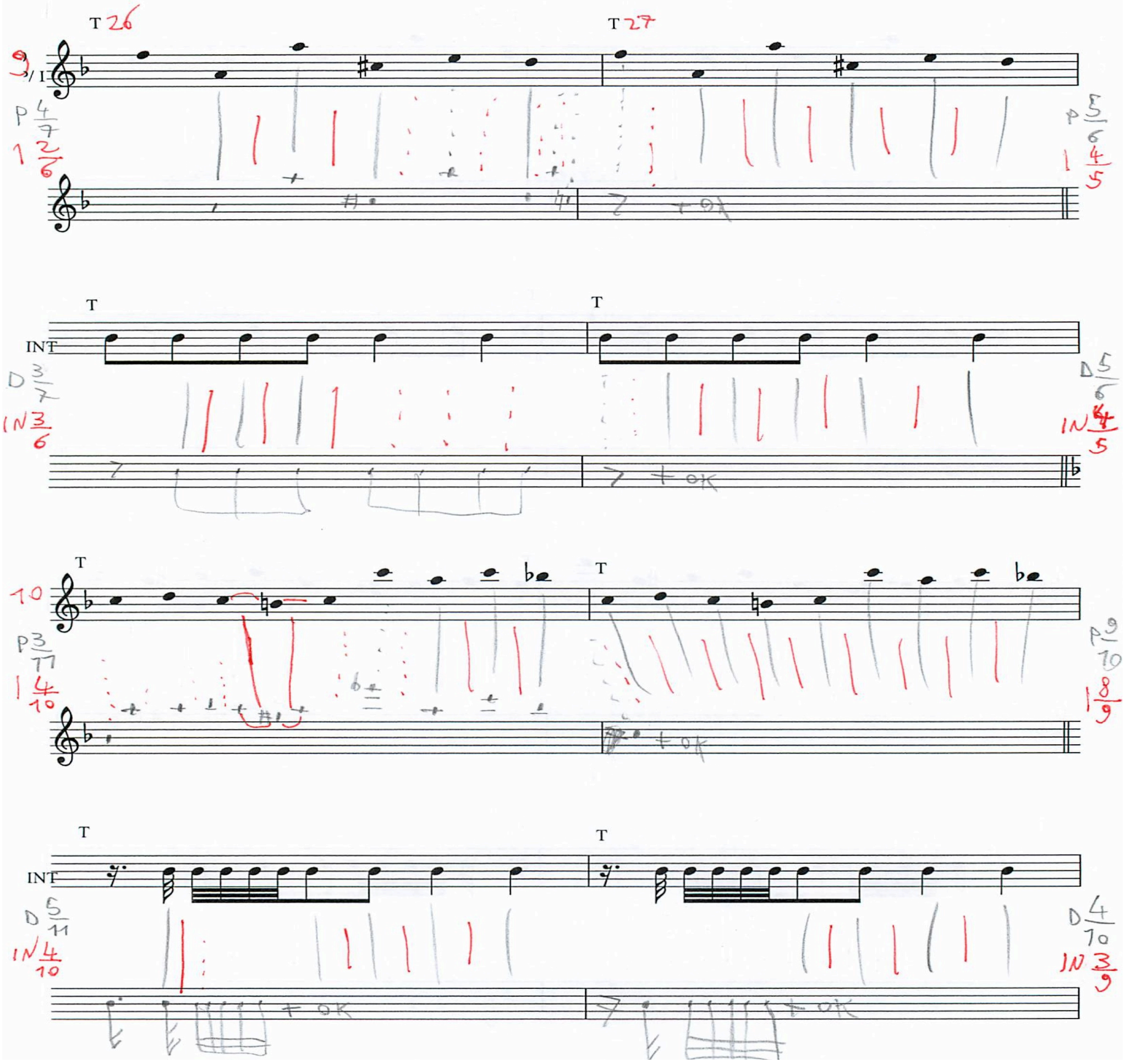
TRIAL:20/27

date: bar:13-14 middle



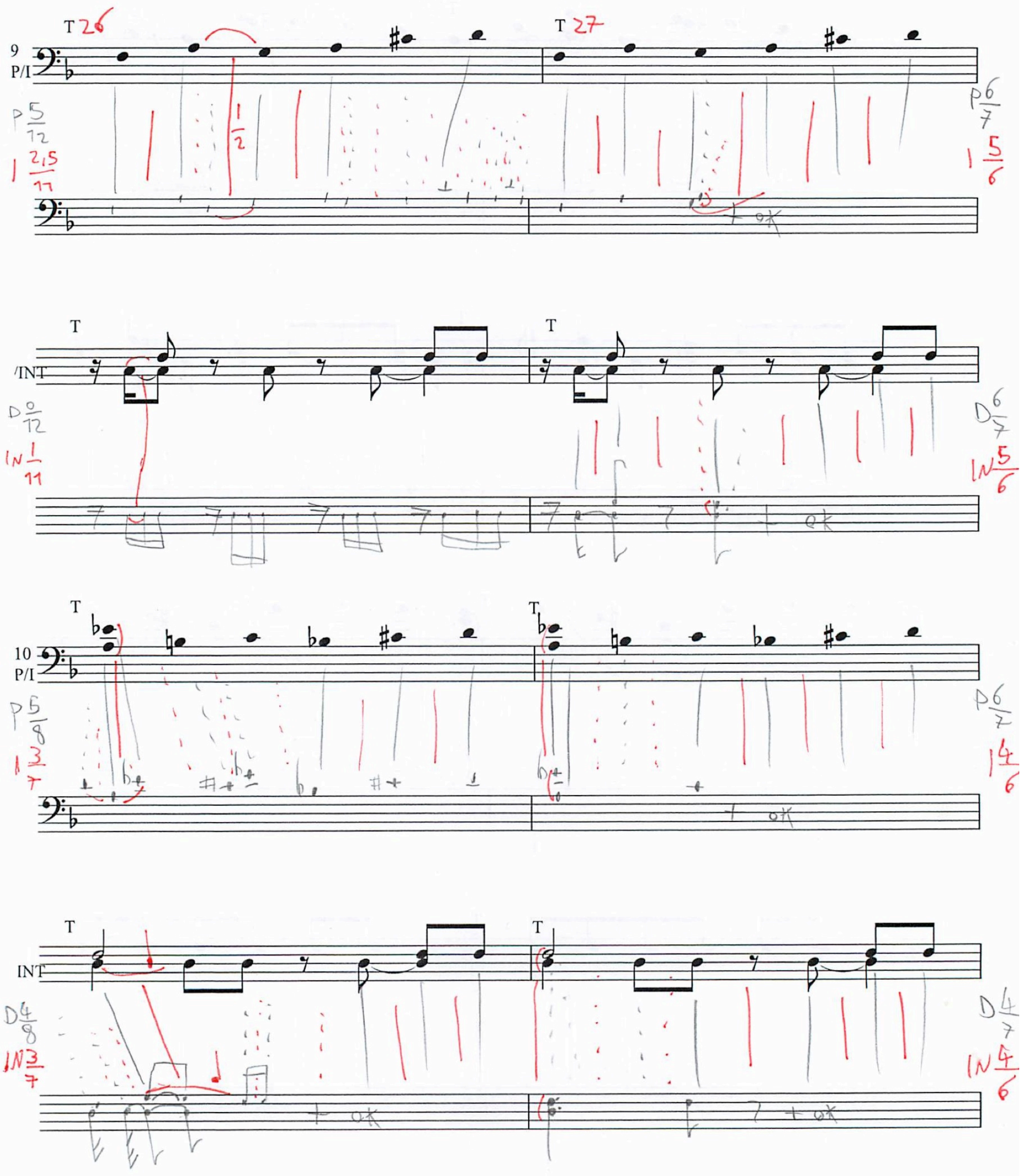
TRIAL: 26/27

date: bar:9-10 top



TRIAL: 26/27

date: bar:9-10 middle



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date: bar:1-2 bottom